OUTLINES

OF

A COURSE OF LECTURES

ON

CHEMISTRY.

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PREFACE.

THE following ſheets contain, as is expreſſed by the title, an Outline of the Author's Lectures on Chemiſtry. They were printed at the repeated requeſt of his auditors, who wiſhed to have a text book which might contain the moſt ſtriking facts. This text book was intended to be confined to thoſe who attended his lectures, but it having been ſuggeſted by ſome friends, whoſe judgment and advice he reſpects, that ſuch a work might be uſeful in refreſhing the memories of others, he has ventured to make it more public. He hopes however, that as this is a mere rude ſketch of what is delivered in the lectures, if his readers ſhould not agree with him in ſome opinions which may appear to be new, they will not cenſure him, till they have had an opportunity of hearing his defence of thoſe opinions.

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ERRATA,

Page 60, line 3, after caloric inſert a comma,

109, 14, for rochelle ſalt, read ſoluble tartar.

OUTLINES, &c.

LECTURE I.

CHEMISTRY may be juſtly regarded as one of the moſt ſublime and important of the ſciences, embracing in its object the whole of natural phenomena; there being few changes, comparatively ſpeaking, that are not attended with ſome effects which come under the conſideration of this ſcience.

Some chemiſts have defined this ſcience negatively, by affirming that every effect which is not merely mechanical, is chemical, and in purſuing this view of the ſubject, we may ſay, that chemiſtry as a ſcience teaches, the methods of eſtimating and accounting for the changes produced in bodies, by motions of their parts among each other, which are too minute to affect the ſenſes individually; and as an art, we ſhould ſay that it conſiſts in the application of bodies to each other, the beſt calculated to produce thoſe changes.

Macquer ſays, that chemiſtry is a ſcience whoſe object is to inveſtigate the properties of bodies by analyſis, and ſyntheſis; and Fourcroy defines it to be a ſcience which gives us a knowledge of the intimate and reciprocal action of all bodies on each other.

It would take up too much time to point out all the advantages which ſociety derives from chemiſtry, it will only be neceſſary to point out a few of the moſt remarkable, with a view of exciting attention, and ſhowing that it is not a ſcience merely calculated to gratify curioſity, and afford entertainment.

Among the arts depending upon chemiſtry, may be enumerated the making of bricks and tiles, porcelain, and in ſhort, all ſorts of earthenware; the making of glaſs; the arts of extracting, melting, and purifying metals, and uniting them with each other; the formation of vinous liquors by fermentation; the diſtillation of ſpirits; the making of vinegar, all depend upon chemiſtry. The art of cookery is likewiſe indebted to this ſcience, as well as the arts of tanning, currying, and the manufacture of white leather, and of hats.

To the apothecary an extenſive knowledge of this ſcience is abſolutely neceſſary, to underſtand what alterations the ſubſtances which he employs may undergo, and that he may, when neceſſary, prevent or correct them; and that he may know the combinations and decompoſitions which take place when different drugs are mixed together.—Numerous miſtakes have ariſen from a want of knowledge of chemical combination and decompoſition in the preparation of medicines.

Chemiſtry is no leſs uſeful to the phyſician than to the apothecary, as it enables him to preſcribe with prudence and ſucceſs, and to apply with advantage thoſe powerful remedies, which the practitioner, ignorant of chemiſtry, adminiſters with a timid and uncertain hand. The arts of dying, bleaching, and callico printing, depend upon chemiſtry, and by means of this ſcience, ſome of them have been lately wonderfully improved. From what has been ſaid it muſt be evident that chemiſtry is the corner ſtone of the arts; and the ſcience of agriculture is much more cloſely connected with chemiſtry than has generally been imagined. The farmer ſhould know how to mix different kinds of earth and manure, ſo as to furniſh the proper nouriſhment to plants in due quantity. The prevention and cure of the diſeaſes of vegetables, and the method of deſtroying the inſects which devour them, depend chiefly on a knowledge of chemiſtry.

The working of mines, and indeed the whole of mineralogy, depends upon chemiſtry; this ſcience teaches us to extract the different metals from their ores, and to render them ſubſervient to the various purpoſes of life.

The advantages of chemiſtry are not however confined to the agriculturiſt, the natural philoſopher, the mineralogiſt, the phyſician, or the artiſt—its phenomena are intereſting to all claſſes of people, and its applications are ſo numerous, that there are few circumſtances which occur in life, in which we do not derive pleaſure and advantage from the knowledge of its principles.

Having pointed out in a general way the utility of chemiſtry, I ſhall proceed to give a very ſhort hiſtorical ſketch of this ſcience.

The origin of chemiſtry is involved in the ſame obſcurity as that of the arts and ſciences in general. What Moſes ſays of Tubal Cain, proves that one part of metallurgic chemiſtry, was underſtood by that patriarch. Tubal Cain would ſeem to be the ſame perſon mentioned in fabulous hiſtory by the name of Vulcan. For many ages after the flood, we have no certain accounts of the ſtate of chemiſtry: the chemical ſkill of Moſes diſplayed in his diſſolving the golden calf, has generally been adduced as a proof of the flouriſhing ſtate of chemiſtry among the Egyptians, in whoſe learning he is ſaid to be well verſed. It ſeems moſt probable however, that Moſes did not diſſolve the calf, but only ground it to powder, and ſuſpended it in water.

But whatever we may think of this circumſtance, it is certainly among the more ancient Egyptians that we ought to place the origin of this ſcience. The firſt of this nation mentioned as a chemiſt, was Athotis, ſurnamed Hermes, or Mercurius, who was a king of Thebes; the next king of Egypt who was a chemiſt, was Siphoas, who lived 800 years after Athotis, and about 1900 before Chriſt; he was ſurnamed by the Greeks, Hermes, or Mercurius Triſmagiſtus. Democritus of Abdera, who lived about 500 years before Chriſt, travelled into Egypt, and obtained a knowledge of their chemiſtry.

After the lapſe of ſeveral ages, during which the progreſs of this ſcience cannot be traced, we again find veſtiges of it among the Arabs. In the ninth century, Gebber wrote three works on chemiſtry, in which ſome uſeful facts are to be found; in the tenth century lived Rhaſis, phyſician to the hoſpital of Bagdat; who firſt applied chemiſtry to medicine. In the eleventh century appeared Avicenna, a chemical phyſician like Rhaſis, and a man of great knowledge and abilities, which elevated him to the office of grand vizier; but the debauched life he led ſoon cauſed his depoſition.

According to writers on alchemy, the art of making gold had been known for a long time; but this notion was carried to its height between the eleventh and ſixteenth centuries; when a great part of Europe was filled with ſearchers for the philoſopher's-ſtone. Among thoſe ſingular men, were particularly diſtinguiſhed Albertus Magnus, Roger Bacon, Arnaud de Villeneuve, Raymond Lully, and Baſile Valentine.

Although the alchemiſts were completely foiled in their reſearches, yet in the ſixteenth century we find a great number of perſons fired by the enthuſiaſm of a gaſconading chemiſt, called Paracelſus, who pretended to have diſcovered an univerſal remedy; ſeveral of his followers who advanced the ſcience conſiderably, were by no means cured of the madneſs which he had communicated; among whom, we may mention Caſſius, Libavius, and Van-Helmont.

Chemiſtry had not hitherto been treated in a philoſophical manner, being entirely compoſed of unconnected facts; but towards the middle of the ſeventeenth century, Barner, phyſician to the king of Poland, publiſhed a methodical arrangement of the facts then known; his work is valuable, as being the firſt that places chemiſtry among the ſciences. Bohine afterwards wrote a philoſophical treatiſe on chemiſtry, which was eſteemed as an elementary work; but Becher went much farther than any of them; he collected all the chemical diſcoveries that had been made, and deſcribed, with ſurpriſing clearneſs all the phenomena then known. He was followed by the celebrated Stahl, who undertook to elucidate the doctrines of Becher, and in accounting for many chemical phenomena, he pretended to demonſtrate the preſence of a principle of inflammability, which he called phlogiſton; his theory was followed till lately by all chemiſts.

Boerhaave cultivated chemiſtry, and enriched it with many valuable diſcoveries, and the celebrated Macquer, contributed the moſt of any to the advancement of this ſcience.

Stahl, entirely occupied in attempting to demonſtrate the preſence of phlogiſton, overlooked the influence of air, on moſt of the phenomena which he explained by his favourite principle: but Lavoiſier afterwards proved, by a variety of experiments, that a part of the atmoſphere combines with bodies during their calcination and burning, and and gave riſe to a ſet of chemiſts who began to doubt the exiſtence of phlogiſton, and who attributed to the abſorption or diſengagement of pure air, all the effects which Stahl thought were owing to the diſengagement or abſorption of phlogiſton. This doctrine poſſeſſes many advantages over that of Stahl, as it does not involve the ſuppoſition of a ſubſtance whoſe exiſtence cannot be proved; and it accounts for almoſt all the phenomena in an eaſy and ſimple manner, ſo that it is now almoſt univerſally adopted.

LECTURE II.

THE particles of matter are endowed with a reciprocal attractive force, which cauſes that arrangement we ſee take place among the different bodies of the univerſe. This attraction takes place either between particles of the ſame kind, or between particles of different kinds: the firſt is called affinity of aggregation, or attraction of coheſion; the latter, attraction of compoſition, or elective attraction.—The attraction of coheſion has very little effect when bodies are diſtant, but when they are brought into contact, they unite firmly together. This kind of attraction modifies the apparent, or phyſical properties of bodies, without influencing in a ſenſible manner their chemical properties. The attraction of coheſion is ſtronger the nearer the particles of a body come in contact, and every thing which tends to ſeparate theſe particles, weakens or oppoſes this attractive force; this effect is produced by heat; which entering, or combining with bodies, diminiſhes the force of attraction. According to the degree with which this force is counteracted by heat, bodies appear in different forms, which may in general be reduced to the following: the hard, or ſolid aggregate, the ſoft aggregate, the fluid, and the aeriform aggregate. Theſe different forms are only different degrees of the ſame attraction, and many bodies are capable of exiſting in them all.

Beſides this attraction exiſting between particles of the ſame kind, bodies of different natures exert upon each other an attraction more or leſs ſtrong; and it is by means of this force, that all chemical changes are effected.

The phenomena of the attraction of combination are regulated by the following laws.

I. It only takes place between the primary, or conſtituent particles of bodies.

II. The attraction of combination between two or more bodies, is inverſely, as the attraction of coheſion.

III. When two or more bodies unite together, in conſequence of the attraction of compoſition, their temperature becomes changed.

IV. The compound which reſults from the combination of two bodies, has properties perfectly different from thoſe of its conſtituent parts.

V. Every body has different degrees of attraction, or affinity for the different bodies with which it unites.

The affinity of compoſition has received different names from its effects, and has been divided into three claſſes: ſimple affinity, double affinity, and intermediate affinity.

When two principles united together, are ſeparated by means of a third, this is ſaid to be performed by ſimple affinity, or ſingle elective attraction.

It often happens however, that when a body is compounded of two others, this combination cannot be deſtroyed either by a third, or a fourth body, but if both theſe bodies are mixed with the compound body, it is then decompounded: this is called double affinity, or double elective attraction. The caſe of intermediate affinity is, when two bodies that have no ſenſible affinity with each other, are united by a ſubſtance which has an attraction for both.

It has been a ſubject much diſputed among chemiſts, whether the attraction of coheſion and combination, be the ſame force that Newton denominated gravity. The facts of which we are poſſeſſed, will not however enable us to decide the queſtion; but we may conclude, that if chemical affinity, and attraction of gravitation, be one and the ſame force, the difference which exiſts in the phenomena produced by them, ſhews that it is modified by particular circumſtances: of this we ſhall be convinced, if we compare what we know of Newton's attraction of gravitation, with the facts of which we are poſſeſſed concerning chemical affinity.

The firſt takes place between large maſſes, and is proportioned to the quantity of matter; the latter exiſts only between the ſmall, and intimate component particles of bodies, and does not take place at all between bodies of conſiderable ſize. The attraction of gravitation takes place at all diſtances; chemical attraction only when the particles are indefinitely near.

LECTURE

LECTURE III.

HEAT, in a philoſophical ſenſe, denotes the cauſe of the power which bodies poſſeſs of exciting the ſenſations of heat, or coldneſs, though theſe terms are not always ſufficiently accurate, owing to our uſing a variable ſtandard of compariſon: for in this inſtance our ſenſations are not to be truſted, becauſe the ſame body may appear hot to one perſon, and cold to another, or even hot and cold to the ſame perſon. Hence it is neceſſary, in order to avoid error, that the ſenſe of the words made uſe of ſhould be accurately defined, and that ſome fixed ſtandard of compariſon be made uſe of inſtead of the human body.

Two opinions have long divided the ſcientific world reſpecting the nature of heat: the one is, that it conſiſts of a peculiar motion, or vibration of the parts of bodies, the other ſuppoſes that heat is a ſubſtance, or fluid, whoſe greater or leſs quantity produces a higher or lower temperature; the latter opinion ſeems better ſupported by facts, but this enquiry will be neither uſeful, or neceſſary in the firſt ſteps of our inveſtigation, for ſince effects are always proportioned to their cauſes, we may ſpeak of the quantities of heat in bodies, without deciding whether they be occaſioned by quantities of motion, or quantities of matter.

The fluid, or motion, or whatever it be, which cauſes the ſenſation of heat in our bodies has been called *caloric* by the reformers of the chemical nomenclature, which is perhaps the moſt unexceptionable term that could have been choſen, ſince it accords with every opinion reſpecting the cauſe of heat. Setting aſide therefore all enquiries concerning the cauſe of heat, we ſhall here confine ourſelves to its effects, or phenomena; and ſhall firſt conſider the moſt general of them, which heat produces on the ſimpler kinds of bodies.

The firſt, and moſt obvious effect which heat produces on bodies, is expanſion; experience has taught us, that at all times when we add heat to a body, we encreaſe its bulk; this is a very general rule, the exceptions are few, and will be noticed afterwards: the only difference is in the degree, or quantity of expanſion produced by equal additions of heat, in which there are ſcarcely two bodies that agree together. In general denſe bodies expand leſs than rare ones, but though this may be looked upon as a kind of general rule, there are ſeveral exceptions to it.

It is owing to this expanſion that the motion of time-pieces is rendered erroneous; but the ingenuity of the artiſt has diſcovered a method of obviating this, by employing the greater expanſion of one metal, to counteract that of another; this is effected in what is called a gridiron pendulum: upon the ſame principle has been contrived a particular conſtruction of watches.

Bodies which are brittle, or which want flexibility, crack or break, if ſuddenly heated, or cooled: this depends upon the expanſive power of heat, that ſtretches the ſurface to which it is applied, while the other parts not being equally heated, do not expand equally, and are of courſe torn aſunder; hence, veſſels which are to ſtand ſudden heat, ought to be very thin. This effect of heat has been applied to ſeveral uſeful purpoſes in the arts.

There are however, ſome exceptions to this very general effect of heat, and particularly in the caſe of water; which, when cooled down to the freezing point, inſtead of contracting on the further application of cold, expands with prodigious force; and this circumſtance enables us to explain ſeveral curious facts. The reaſon of this expanſion has not been properly explained, but may perhaps depend, as Dr. Black ſuppoſes, on ſome polarity in the attraction, which diſpoſes the particles of the water to unite into a ſolid, and which at the ſame time diſpoſes them to run into certain lines and figures, inſtead of uniting ſimply together; in conſequence of which, little vacuities will be left in the maſs, cauſing it to occupy more room.

Another exception to this general rule, occurs in the caſe of caſt-iron, which ſwells, or expands conſiderably in the act of becoming ſolid; and this is the reaſon why it takes ſo fine and ſharp an impreſſion from the mould.

There is one curious obſervation reſpecting the hiſtory of heat, namely, that it never adds in the leaſt to the weight of a body, ſome experiments which were thought to prove the contrary, have been made, but they are by no means deciſive.

We ought to have this effect which heat poſſeſſes of expanding bodies in view, when we conſider their ſpecific gravities.

Some bodies conduct heat much more quickly than others; metals, for inſtance, conduct heat with much greater rapidity, than wood, glaſs, or earthenware; and on this account hot liquors grow cold ſooneſt in metallic veſſels.

Heat is greatly retarded in its progreſs, by rare and ſpungy ſubſtances, ſuch as cork, feathers, or wool; which keep the body warm, by preventing its heat from eſcaping, and not by any warmth which they themſelves poſſeſs: in the ſame manner, ſnow protects the ſurface of the earth from the intenſe cold which would be fatal to vegetation.

If any number of *inanimate* bodies, of different temperatures, be brought together, in a place where there is no poſitive cauſe of heat, the heat will flow from the hotter bodies to the colder, till there be an equilibrium. But this is by no means the caſe with reſpect to *animated* matter; for, whatever be the degree of heat peculiar to individual animals, they preſerve it nearly unchanged in every temperature;

rature ; which ſhews, that they neither receive their heat from the bodies ſurrounding them, nor ſuffer from external circumſtances, any material alterations in their heat ; which leaves us no room to doubt, that they are furniſhed with a power of generating, ſupporting, and regulating their own temperature. We ſhall afterwards be enabled to ſee on what this power depends.

LECTURE IV.

BEFORE we proceed farther reſpecting heat, it will be neceſſary to ſay ſomething concerning thermometers; which are very uſeful inſtruments, and which have greatly enabled us to enlarge, and correct our ideas reſpecting heat. The invention of the thermometer is involved in obſcurity, but Sanctorio ſeems to have the beſt claim to it: he appears to have been the firſt who noticed the expanſive power of heat; and obſerving it in the caſe of air, thought of employing it to aſcertain the different degrees of heat. Sanctorio's aerial thermometer, afterwards improved by Mr. Boyle, was remarkably ſenſible; but, as it was liable to be affected by variations in the weight of the atmoſphere, as well as of its heat, it could not be depended on. The object therefore, was to conſtruct thermometers with ſome other fluid than air, which would not need to have any communication with the atmoſphere. Spirit of wine, tinged of a red colour, was firſt uſed for this purpoſe, and is, even ſtill preferred by ſome; though mercury is now generally uſed, and is undoubtedly the moſt proper fluid for the purpoſe. The only difficulty which remained, was to graduate them in ſuch a manner, that all thermometers might exactly correſpond with each other, which at firſt ſight was by no means obvious. The firſt attempts were very rude, and imperfect; neither was the method propoſed by Mr. Boyle much to be truſted to; as, it depended on the meaſurement of the capacity of the ball, and bore of the tube, by mechanical means, which could not accurately be done.

It was afterwards diſcovered, that ſome bodies always changed their form at the ſame temperature, or, that when they paſs from a ſolid, to a fluid ſtate, and the contrary, they always reduce the fluid in the thermometer to the ſame degree of expanſion, ſo that, by obtaining two, or more, ſuch fixed points, thermometers may be graduated ſo as to correſpond exactly with each other. It is likewiſe found, that the dilatations and contractions of mercurial thermometers, are very nearly proportionate to the quantities of heat communicated to, or ſubtracted from them, which is a very ſatisfactory diſcovery, and which was aſcertained by producing three different temperatures independent of a thermometer, and which were intended to ſerve as a check upon it, and ſhew whether it pointed to the different quantities of caloric that really obtained.

Theſe thermometers, are however, liable to ſome imperfections: the firſt is, that they are incapable of meaſuring great degrees of heat; becauſe the fluid which they contain, when heated above a certain degree, is converted into an elaſtic vapour that would burſt the veſſel.

Mr. Wedgewood has however, contrived an ingenious method of meaſuring any degrees of heat, however intenſe, by means of ſmall pieces of clay, which contrary to the general rule before mentioned, contract in proportion to the degree of heat to which they are expoſed.

Another inconvenience to which thermometers are ſubject, is, that we cannot by means of them aſcertain the degree of heat or cold that happens in our abſence. This is obviated in a great meaſure by Mr. Sixe's ingenious thermometer, the indices of which point to the greateſt degrees of heat or cold that take place during any length of time that the obſerver may be abſent. This thermometer, though very ingeniouſly contrived, is too complicated for common uſe, and not portable; but a much more ſimple one on the ſame principle might be eaſily contrived.

There are a variety of ſcales adapted to thermometers, different ones being uſed in different countries; which is a circumſtance attended with no ſmall inconvenience in comparing obſervations that have been made with various thermometers; and it is much to be wiſhed that a general or ſtandard ſcale were adopted. The ſcale uſed in this country is that of Farenheit, which is particularly deſcribed in the lecture.

LECTURE V.

HEAT enters with equal celerity into different kinds of bodies, but they are not all equally eaſily ſaturated with it, or in other words, have unequal capacities for receiving it.

The celerity with which heat paſſes from hotter bodies to colder, is, *ceteris paribus*, in proportion to their difference of temperature; and alſo to the extent of contact: Hence the exceſſive ſlowneſs with which heat is communicated from one part to another in bodies that are more ſpungy and light, while it readily paſſes through thoſe that are denſe and heavy. It is on this account that light ſpungy ſubſtances, ſuch as feathers and wool, keep us warm in cold weather, as was obſerved before. From this likewiſe we ſee the reaſon why ſnow, when it lies pretty thick upon the ſurface of the earth, prevents its being cooled much below the freezing point, and thus preſerves the roots of vegetables from thoſe intenſe colds which would otherwiſe deſtroy them.

We daily ſee bodies rendered fluid by means of heat, and have reaſon to be perſuaded, that whenever we meet with fluidity, it is always an effect, or conſequence of heat: even thoſe bodies which appear generally in a fluid ſtate, and which ſtate might ſeem to be natural to them, derive their fluidity from the quantity of heat which they contain. Heat may therefore be conſidered as the cauſe of fluidity in all bodies whatever; but as there is a great diverſity with regard to the *quantity* of heat neceſſary to produce this effect, it would appear that there are ſome other circumſtances that affect their diſpoſition to fluidity.

We may however conſider all fluid bodies, as ſolids melted by heat, but whoſe congealing point is lower than the natural temperature of the atmoſphere.

Some philoſophers have found great difficulty in admitting this general propoſition; and have thought water an exception. They have ſuppoſed fluidity to be an eſſential quality of water, depending upon the ſpherical figure of its particles, and that its freezing depends upon the introduction of extraneous bodies; of this opinion was profeſſor Muſchenbrook, who has given a number of arguments in favour of this ſuppoſition, none of which are however ſatisfactory.

It has been generally ſuppoſed, that bodies in paſſing from a ſolid to a fluid ſtate, receive no more heat than what is indicated by the thermometer, and that the extrication of this *ſenſible* heat, is ſufficient to reduce them again to a ſtate of ſolidity; but the exceſſive ſlowneſs with which ice melts, when ſurrounded by an atmoſphere, many degrees above froſt, and which muſt therefore be conſtantly communicating heat to it; as well as ſome curious phenomena attending the freezing of water, ſhew that the heat muſt be received in ſome different manner.

According to Dr. Black, the fluidity of bodies does not depend ſo immediately upon the *ſenſible* heat which they contain, as upon a certain quantity of *latent* heat, which is combined with, or lies concealed in the maſs, ſo as not to appear to the ſenſe, or affect the thermometer; but which is ready to break out, and aſſume the ordinary form of ſenſible moving heat. A certain quantity of ſenſible heat he ſuppoſes neceſſary to fluidity, but the immediate and indiſpenſable cauſe is, the entrance of a certain quantity of heat which becomes chemically combined with the body, and which continues in this condition, without ſuffering any increaſe or diminution, while the body continues fluid, but when it paſſes to the ſolid ſtate, this heat becomes diſengaged, and enters into the ſurrounding bodies, augmenting their temperature. A fluid may hence be conſidered as a body combined with caloric.—The ſolid form is therefore the natural ſtate of water; in a fluid ſtate, it is a combination of ice and and caloric. The quantity of heat which enters ice, and which gives it fluidity without augmenting its temperature, may be calculated.

Dr. Black, from ſome experiments which he made, ſuppoſes the heat neceſſary to melt ice, without augmenting its temperature, to be 147°; but ſome other philoſophers, who have conſidered the ſubject more accurately, have found that ice cannot become water, unleſs it receive 130° of heat. This ingenious theory enables us to explain many phenomena relating to heat and cold, which cannot otherwiſe be accounted for ; such as the extreme degrees of cold produced by mixing different ſalts with ſnow, or with the mineral acids ; the exceſſive ſlowneſs with which ice melts ; the reaſon why melted metals when in large quantity are ſo long in becoming ſolid, &c.

LECTURE VI.

TO form a more exact idea of the converſion of fluids into elaſtic vapours, ſuppoſe a ſingle drop of water put into a copper or braſs globe, capable of holding ſome gallons, and the globe perfectly exhauſted of its air; if we apply heat to it, and had an opportunity of ſeeing what happens within, we ſhould find that the water would ſuddenly diſappear, and aſſume the form of a tranſparent vapour, which would immediately fill the whole cavity of the globe in an equable manner; and if the heat be further increaſed, the elaſticity, expanſion, or force of the vapour, will be increaſed to ſuch a degree as to burſt the globe.

In general, the converſion of any particular body into vapour, depends upon its being heated above a certain degree; and this vapour immediately collapſes, as ſoon as the heat is diminiſhed below that degree.

This degree is much higher than that required to convert them into a ſtate of fluidity; and every body has a particular degree of heat at which it aſſumes the form of vapour, in the ſame manner as each requires a peculiar degree of heat to reduce it to fluidity. It is not found however, that thoſe bodies which ſooneſt aſſume the form of a fluid, require the loweſt degrees of heat to convert them into vapour; for though this may be regarded as a kind of general rule, there are many exceptions to it.

Thoſe ſubſtances which are eaſily converted into vapour, are called *volatile*, and thoſe which require a very ſtrong heat, are called *fixed.*

Though the degree of heat required to convert a particular body into vapour, is in general nearly the ſame, yet it is not ſo ſteady as the melting point; for we find, that when preſſure is applied to the ſurfaces of bodies, it retards very much their converſion into vapour, and enables them to bear a much greater heat before they boil. In Papin's

Digeſter, water will bear to be heated nearly red hot, without being converted into vapour.

Under the preſſure of the atmoſphere, all bodies are found to receive more heat than they otherwiſe would do, and when we conſider that this preſſure is fifteen pounds upon every ſquare inch, we ſhall not be ſurprized that it ſhould enable water to bear 120°. more heat before it boils, than is required to make it boil in vaccuo.

When heat is applied to the bottom of a veſſel containing water, as ſoon as it becomes heated to a certain degree, it is affected with that agitation which we call boiling, which is occaſioned by the ſmall bubbles of vapour formed at the bottom of the veſſel, where the heat enters moſt plentifully; this vapour being much lighter than the water, riſes rapidly through it, and is thrown up to the ſurface with violence.

The violence of this agitation is proportioned to the celerity with which heat is thrown in, and however long or violently the fluid is made to boil, it will not become the leaſt hotter.

The operation of heat in producing vapour, is ſimilar to its operation in producing fluidity. The converſion of a body into vapour does not depend ſo immediately upon the quantity of *ſenſible* heat, as upon a quantity of heat which becomes abſorbed, or latent, in ſuch a manner as not to be evident to the ſenſe of touch, or to the thermometer; but which is ready to break out, when the body is condenſed into the form of an incompreſſible fluid.

This opinion is confirmed by ſeveral obſervations, particularly by the great quantity of heat received by water during its ebullition, which does not appear in the vapour, but which is given out by the vapour when it is condenſed in the proceſs of diſtillation.

There are other examples which ſhow the change of ſenſible into latent heat, during the converſion of bodies from their ordinary ſtate into that of vapour. If the bulb of a thermometer be moiſtened with ether, the mercury will ſink in the tube on the evaporation of the ether; and if the preſſure of the air be removed from the ſurface of the ether, it will evaporate ſo quickly as to produce a very great degree of cold, if a tube be filled with water, and immerſed in the ether, the water will ſoon be frozen by the evaporation of the ether.

A very great degree of cold may be produced by mixing neutral ſalts with the mineral acids in various proportions. The cold produced in this way is ſo intenſe, that mercury may be frozen at any time when the temperature of the air does not exceed 85° of Fahrenheit's ſcale.

LECTURE VII.

THOUGH it is evident from what has been ſaid, that the different forms under which bodies appear, depend upon their latent heat, or caloric which is combined with them; yet their permanency, or continuance in any form, depends on their quantity of ſenſible heat. Water is ſolid in all degrees below 32°. of Fahrenheit's ſcale, it then is diſpoſed to combine with caloric, and become a fluid; it retains its fluidity under the ordinary preſſure of the atmoſphere, till its ſenſible heat is augmented to 212°. It is then diſpoſed to abſorb a much larger portion of caloric, and is converted into a gas, or elaſtic vapour, in which ſtate it would always continue, if the heat of the atmoſphere was above 212°.

Ether boils, or is converted into an elaſtic fluid, when heated up to 106°, and if we could keep it in this degree of heat, it would always be in the form of an elaſtic fluid.

All gaſes, or elaſtic fluids, therefore, depend upon the combination of particular ſubſtances with caloric; and thoſe which we call permanently elaſtic, are only ſo, becauſe we cannot ſo far reduce their temperature, as to diſpoſe them to part with their latent heat, otherwiſe they would undoubtedly become fluid or ſolid.

Though the vaporific point of moſt bodies is higher than what is neceſſary for their fluidity, this is not the caſe with regard to all; for there are ſome ſolid bodies which begin to be converted into vapour by a ſmaller degree of heat than is neceſſary to render them fluid.

From obſervations on the manner in which vapour is produced from different bodies, we can underſtand ſeveral chemical operations, ſuch as evaporation, diſtillation, and ſublimation. With regard to evaporation, we may lay down the following general conſequences.

1. If any thermometer be plunged into an evaporable

porable fluid, and immediately taken out again, the mercury will deſcend ſeveral degrees while the bulb is drying; but as ſoon as the fluid is evaporated, it will begin to riſe, and continue to do ſo, till it has acquired the temperature of the ſurrounding air.

2. The cold produced is greater in proportion as the fluid is more evaporable.

3. If the evaporation be accelerated by any means, excepting heat, the cold will be proportionally augmented.

Though the property of producing cold by evaporation has been but lately obſerved by chemiſts, yet it has been long employed by thoſe who knew nothing of the operation. In hot climates they employ it to cool their liquors, and even to keep the temperature of the body cool.

The making of ice in warm climates, where it is one of the luxuries of life, depends on the ſame principle.

On this principle alſo we can ſee the reaſon why the air over a wood or foreſt is cooled by evaporation from trees and ſhrubs, and hence the ſhade formed by vegetable bodies, is more effectual in cooling us, than the ſhade of rocks and buildings.

When the human body is heated, the vapour paſſes off through the ſkin by perſpiration. If this perſpiration be leſſened, what ſhould evaporate, heats the body to an improper degree. Hence the utility of remedies which promote perſpiration, and the uſe of ether when applied to the temples and different parts of the ſurface of the body.

Spontaneous evaporation is the production of a vapour from bodies, diſtinct from that elaſtic vapour produced by increaſing their heat above their boiling point; it is produced ſlowly and imperceptibly, without the leaſt agitation; it is evident therefore that it muſt proceed from the ſurface, and is accordingly found to be more copious as the ſurface is increaſed; but if the air, loaded with this vapour, be allowed to ſtagnate upon the ſurfaces of the bodies from which it has been produced, the fluid will not evaporate by any means ſo faſt as it did before. Hence in calm weather, water evaporates more ſlowly than when the air is agitated by winds.

The production of this vapour, though it does not appear to poſſeſs any elaſticity, depends however upon heat; and when a conſiderable quantity of it has been produced, and the heat ſuddenly diminiſhed, the vapour will be condenſed, and form a miſt or dew; or if the cold be great, a hoar froſt.

It is this evaporation which is going on from the ſurface of the ſea, lakes, rivers, and the earth, which produces the vapour, that at a certain height is condenſed by cold into miſt, and compoſes clouds, which are ſuſpended at different heights in the atmoſphere; which are carried about by the air, and are liable to become electric, and in conſequence of this produce the phenomena of thunder and lightning: theſe clouds being farther condenſed, fall in drops of rain, which form ſprings and lakes, from whence ariſe rivers and ſeas.

On account of the importance of ſpontaneous evaporation in many of the grandeſt operations in nature, various attempts have been made to explain its cauſe, particularly by Derham, De Saguliers, and others; none of which are however ſatisfactory. One of the moſt ingenious theories is that given by Dr. Hamilton. He ſuppoſes that ſpontaneous evaporation, which takes place in low degrees of heat, depends on the attraction between the air and the water; and that the air diſſolves water in the ſame manner that water diſſolves ſalt, and many chemical fluids diſſolve metals. This theory is ſupported by a number of circumſtances, in which it ſeems to agree remarkably with the diſſolution or combination of ſalts or metals with fluids, and to account very well for the phenomena; but there is an inſurmountable objection to it; viz. that this evaporation goes on in vaccuo, even more rapidly than in the open air, which it could not do if it depended on the ſolution of the water in the air.

A variety of circumſtances, and particularly the cold which is produced by ſpontaneous evaporation, ſhew, that this, as well as the formation of other vapours, depends upon the abſorption of heat into a latent ſtate.

When heat is accumulated in bodies to ſuch a degree that they emit light, they are ſaid to be *ignited.* There ſeems a curious connexion between light and heat; when a body is heated intenſely, it always becomes luminous, and the light of the ſun; when concentrated, is capable of producing a moſt intenſe heat in opaque bodies. But though there would ſeem this ſtrict connexion between them, it ſeems probable that the light of the ſun does not contain any heat. The rays of the ſun, in their moſt concentrated ſtate, produce no heat when they fall upon tranſparent bodies. If the rays of the ſun communicated heat to the earth, this planet would be gradually heated to an intenſe degree, as there does not ſeem any way in which the heat can be conveyed from it to other bodies. It appears much more conſonant to the phenomena, to ſuppoſe that the rays of the ſun, falling upon bodies, become attracted by, and combined with them, and thus diminiſh their capacity for heat, ſo that their combined caloric will be diſengaged and become ſenſible. There exiſts probably therefore, always the ſame quantity of caloric in the earth, and the atmoſphere which ſurrounds it; and this caloric is either in a combined or free ſtate. Different proceſſes diſengage the combined caloric, which then becomes free.

When a piece of iron is made red hot, the light is perhaps given out by the oxygen, on its union with the ignited body; ſo that the red appearance of iron is moſt probably a ſpecies of combuſtion. The ſame body not only always requires the ſame degree of heat before it becomes red, but all kinds of matter capable of bearing a red heat, become red about the ſame time.

As light is an agent of ſome conſequence in chemiſtry, it may not be improper to conſider ſome of its properties here, though the moſt remarkable belong to the ſcience of optics. I ſhall only therefore give a very ſhort view of its phyſical properties.

Light ſeems to conſiſt of particles of matter, extremely minute, which are emitted from the ſun, and other luminous bodies, in right lines; its veloſity is ſo great, that it moves from the ſun to the earth in little more than eight minutes. The elaſticity of the rays of light is ſo great, that the angle of incidence is equal to the angle of reflexion. Light has gravity, for it may be attracted and inflected by different ſubſtances.

The light of the ſun, which is white, is compoſed of rays of ſeven different colours, which may be ſeparated by refraction in the following order.—Red, orange, yellow, green, blue, indigo, violet.

Light is now no longer conſidered as a mere phyſical agent; the chemiſt is ſenſible of its influence in a variety of operations. Vegetation cannot go on in perfection without light, for plants deprived of it are perfectly white and weak; and when the light is permitted to enter into a dark place where vegetables are growing, they all tend towards it, as if ſenſible of the neceſſity of this fluid to their exiſtence.

Deprived of the benign influence of light, the colour of all vegetables would be a deadly white; they are even deprived of their beautiful tints which they have already acquired, when they are ſhut up in darkneſs. Vegetables not only owe their colour to light, but alſo their odour, ſavour, and combuſtibility. We ſee the influence of this element likewiſe exerted on other bodies. Worms, and inſects which live in darkneſs, are white; ſo are the birds, and butterfly tribe, which fly about only in the night. Several experiments made by Scheele and Berthollet, ſhew that the abſence or preſence of light, varies and modifies in an aſtoniſhing manner, the reſults of chemical operations.

Inſtances have been already given in which cold is produced by mixture; many likewiſe occur in which heat is produced. When cold was produced, it was ſhown that heat was abſorbed, and became latent in the mixture; but here, that heat which was before latent, becomes ſenſible.

LECTURE VIII.

IN this lecture the laws of chemical affinity, or affinity of compoſition, illuſtrated in the ſecond lecture, are recapitulated, and afterwards the effects which take place when bodies are mixed together, are conſidered.

In ſome inſtances, when bodies are mixed together, they cannot by any means be made to combine, or unite: as is the caſe with mercury, ſand, or oil, when mixed with water. However violently theſe bodies are agitated, they will ſoon ſeparate. In other inſtances however, bodies on being mixed together, readily unite, and form a homogeneous compound, in which we cannot diſcover the ſmalleſt appearance of any diverſity of conſtituent parts. In ſome caſes this intimate union is effected ſlowly, and in a gentle manner, and is not accompanied by any phenomena which attract the attention; but there are other bodies whoſe union is attended with a violent agitation, and the production of heat. In ſome inſtances the commotion is very violent, and the mixture breaks out into a cloud of ſmoke, or even into flame. Theſe circumſtances are particularly applicable to the union of fluids with each other; but there are many inſtances in which ſolids, even very hard bodies, upon being thrown into certain fluids, are torn aſunder. In all caſes where the ſolid is thus divided, and united to a fluid, it is called by chemiſts a *ſolution*, and the fluid is called the *ſolvent*. It is neceſſary to diſtinguiſh between ſolution and diffuſion. When a piece of clay is mixed with water, it will become diffuſed in it, but the mixture will be turbid, and in time the clay will ſeparate from the water and fall to the bottom, as there is no chemical combination between them. In all caſes of real ſolution, the compound becomes tranſparent, ſo that tranſparency may be regarded as a general criterion of ſolution.

When a liquid has diſſolved a certain quantity of a ſolid, if more be added, it will not be diſſolved; the liquid is then ſaid to be ſaturated with the ſolid.

A curious circumſtance takes place in ſome inſtances of ſolution, which is not eaſily accounted for. When a fluid has diſſolved as much of a certain ſolid as it can, it will ſtill diſſolve the particles of another body; and when it is ſaturated with this, it will diſſolve a third, and ſo on. This is however only true with regard to ſome particular ſolvents, for in others, when a third ſubſtance is added, it cannot be diſſolved, unleſs the body previouſly diſſolved ſhould be precipitated.

When ſubſtances are combined which differ in volatility, they may be ſeparated by heat, which converts the more volatile body into vapour, while the leſs volatile remains. Two bodies may likewiſe be ſeparated from each other by the addition of a third body; of this a number of inſtances may be given.

There are few ſubſtances found in a natural ſtate, whoſe conſtituent parts cannot be ſeparated from each other, by ſome of the methods uſed in chemiſtry. One of the principal methods conſiſts in altering the temperature of bodies. The parts of ſome bodies are ſeparated from each other by expoſing the compound body to a great degree of cold, when ſome of its parts will congeal, while the others remain fluid; but the purpoſes of chemiſtry are in general, much better anſwered by raiſing, than by lowering the temperature of bodies. The moſt uſual way of heating bodies, is to place them in communication with others which are in a ſtate of combuſtion. The veſſels and furnaces made uſe of for theſe purpoſes, are various, according to their ſeveral applications.

When ſubſtances of conſiderable fixity are to be expoſed to heat, or when the volatile parts of bodies are propoſed to be diſſipated into the air, open veſſels are uſed.

The common culinary utenſils of copper or iron, anſwer theſe intentions, when the matter to be operated on, will not corrode them. Glaſs veſſels are the moſt cleanly, and may be uſed for a great variety of chemical purpoſes. They have the advantage of reſiſting the moſt corroding matters, and their tranſparency affords the valuable convenience of ſeeing the changes which happen within them.

In moſt operations where the volatile parts of bodies are propoſed to be ſeparated and preſerved, it is neceſſary to uſe cloſe veſſels. The apparatus generally uſed for this purpoſe, is the common ſtill. But there are many matters required to be diſtilled, that are not ſufficiently volatile to paſs into the receiver in this way. In ſuch caſes the refrigeratory is omitted, and a retort is uſed, with a receiver luted to its neck.

The conſtruction of furnaces is as various as the purpoſes they are deſigned to ſerve. A lamp ſupported at different diſtances below any chemical veſſel, or burning with a variable number of wicks, is very uſeful when moderate degrees of heat are intended to be applied. For higher degrees, furnaces of different conſtructions muſt be uſed. Chemical veſſels may be plunged to a greater or leſs depth in a pot placed over the furnace, containing ſand, water, or other matter capable of ſuſtaining heat. Theſe ſubſtances interpoſed between the veſſel and the fire, compoſe what is called by chemiſts a bath, and are very uſeful in imparting an uniform heat, not ſubject to the ſudden viciſſitudes experienced by veſſels expoſed to a naked fire. Without this contrivance, glaſs veſſels would often fly and crack. Glaſs or earthen veſſels intended to ſuſtain a greater heat than can be given by means of a bath, muſt be coated. A valuable method is adopted by Mr. Willis, to ſecure and repair his retorts uſed in the diſtillation of phoſphorus.

The philoſophical chemiſt may in general perform his operations without the abſolute neceſſity of uſing furnaces conſtructed on purpoſe, or preparing any large apparatus of veſſels. A tobacco-pipe is a very good crucible, with which many experiments may be made in a common fire, with the aſſiſtance of a pair of bellows. Common chafing diſhes, or the larger ſort of black lead crucibles, may be applied to purpoſes of extenſive utility.—A Florence flaſk will form as good a retort as can be uſed, and a phial with a wide neck, luted to the flaſk, will ſerve as a receiver.

The blow-pipe is an inſtrument of great uſe in the chemical examination of bodies, particularly minerals. The advantages attending experiments with this inſtrument, are many. They may be made in a very ſhort time, in any place, by an apparatus that admits of being carried in the pocket; the quantity required of any material is ſo ſmall, that they are performed at very little expenſe, and the whole proceſs is viſible from the beginning to the end. If inſtead of air from the lungs, or a pair of bellows, oxygen gas be uſed with the blow-pipe, a greater a greater degree of heat may be obtained, than by any other method yet diſcovered. In making experiments on gaſes, or aeriform fluids, it is often neceſſary to pour them out of one veſſel into another, and to mix them together; this may in general be done under water, in a ciſtern proper for the purpoſe, ſuch as Dr. Prieſtley uſed in his experiments on airs. But many kinds of air combine with water, and therefore require to be treated in an apparatus in which mercury is made uſe of. This fluid being very ponderous, and of conſiderable price, motives both of convenience and economy require that the apparatus ſhould be made much ſmaller than when water is uſed.

LECTURE IX.

THE earth is surrounded or encompaſſed by a thin tranſparent, inviſible fluid, called the atmoſphere, which reaches to a conſiderable height above its ſurface. This fluid, though inviſible to us, is a real ſubſtance, as appears by its excluding other ſubſtances from the ſpace which it occupies. It is likewiſe heavy, and preſſes with conſiderable force, and as it is a fluid, it preſſes like other fluids equally in all directions.

The weight of the air is the cauſe of the ſuſpenſion of mercury in the barometer, and of the action of pumps. The weight of atmoſpheric air is to that of water nearly as 1 to 900, and the atmoſphere near the earth's ſurface, preſſes with a weight of fifteen pounds upon every ſquare inch.

As air is an elaſtic fluid, it is capable of occupying more or leſs ſpace according to the preſſure it ſuſtains, and its ſpring or reſiſtance is always proportioned to that preſſure.

Theſe properties are called the mechanical or phyſical properties of the air; but whether it be a ſimple homogeneous fluid, or conſiſts of a mixture of gaſes, belongs to the province of chemiſtry to aſcertain. Chemiſtry affords two general methods of determining the conſtituent principles of bodies, analyſis and ſyntheſis; both of which can be uſed in the moſt ſatisfactory manner in our inveſtigations of the nature of atmoſpheric air. From ſome ingenious experiments, M. Lavoiſier has proved, that the air of the atmoſphere is not a ſimple homogeneous fluid, but conſiſts of two elaſtic fluids, poſſeſſed of very different properties; one of which ſupports combuſtion, and animal life much better than common air; and the other is incapable of ſupporting either for an inſtant. Theſe two fluids exiſt in the atmoſphere in the proportion of twenty-ſeven of the former, to ſeventy-three of the latter.

The atmoſphere contains ſome other gaſes, or ſubſtances capable of being diſſolved or ſuſpended in it, but in ſmall quantity, and theſe are the two principal ſubſtances of which it is compoſed.

In the new Nomenclature, the terms are taken chiefly from the Greek language, in ſuch a manner as to make their etymology convey ſome idea of what is meant to be repreſented, and theſe are made ſhort, and contrived in ſuch a manner as to be eaſily changeable into adjectives and verbs. Following theſe principles, the term gas has been retained, and the numerous claſs of aeriform elaſtic fluids have been arranged under that name. Gas therefore in the new Nomenclature, becomes a generic term, expreſſing the fulleſt degree of ſaturation of a body with caloric. To diſtinguiſh each ſpecies of gas, a ſecond term is employed for the name of the baſe, which ſaturated with caloric, forms each particular gas.

The pure part of the atmoſphere is called *oxygen gas*, from the moſt general property which its baſe poſſeſſes of forming acids, by combining with different ſubſtances. The chemical properties of the noxious portion of the atmoſphere being but little known, the name of its baſe is taken from its known quality of killing animals, and is therefore called *azote.* Hence the name of the noxious part of the atmoſpheric air is *azotic gas.*

This term is certainly not the moſt proper that might have been choſen, becauſe it does not point out any excluſive characteriſtic of the ſubſtance, and it is ſurprizing that the authors of the new Nomenclature did not call it *nitrogen,* which would have been unexceptionable, and perfectly agreeable to the principles on which the new Nomenclature is founded.

From the numerous improvements and diſcoveries lately made, chemiſtry was become a ſcience of the utmoſt importance; and many of the ancient terms being very barbarous, as well as conveying falſe ideas, a new Nomenclature became highly neceſſary.

The method adopted for fixing the names of compound ſubſtances, ſeems ſimple and natural; as will appear from the following inſtances.

The authors of the new Nomenclature begin with comprehending under a general denomination, the combination of any acid with its different baſes; and in order to ſimplify the ſubject, and aſſiſt the memory, they have given the ſame termination to all the words which denote the combinations of acids, ſuch as *ſulphat*, *nitrat*, and *muriat*, to denote the combination of the ſulphuric, nitric, and muriatic acids, with different ſubſtances. The ſpecies of combination is known by adding to this generic name, that of the body which is combined with the acid.

Some of the bodies which are convertible into acids by union with oxygen, are capable of different degrees of ſaturation with that principle, by which their properties become altered. When a body is completely ſaturated with oxygen, the termination is *ic*, as the *ſulphuric acid*, but when it is combined with it in a ſmaller degree, the termination is *ous*, as the ſulphurous acid.

LECTURE X.

THE diſcovery of *oxygen gas* is perhaps the moſt important that ever was made in Chemiſtry. This elaſtic fluid was diſcovered by Dr. Prieſtly in the year 1774. Since that time it has been extracted from a variety of ſubſtances.

When a metal is expoſed to the air, and at the ſame time to heat, it loſes its metallic luſtre, and acquires the form and properties of an earthy ſubſtance. If this change be produced in a given quantity of atmoſpheric air, the calcination can only be carried on to a certain degree; and on examining the air which remains, we ſhall find that it has loſt the whole of its oxygen, and that nothing remains but the azotic gas. If we examine the metallic calx, we ſhall invariably find it heavier than the metal from which it was produced, and this augmentation of weight will be exactly proportioned to the loſs of weight ſuſtained by the air.—Hence it appears that the oxygen of the air becomes united to the metal during calcination. On expoſing the calx, or oxyd of mercury to a conſiderable heat, the metal will be revived, and a quantity of oxygen gas may be procured from it. If the calcination of a metal be performed in pure oxygen gas, it will go on much more rapidly than in atmoſpheric air, and if the quantity of metal be ſufficient, all the air will be abſorbed,

Since oxygen gas contains a large quantity of caloric, and light, in a latent or combined ſtate, we ſhould expect that when the oxygen becomes fixed in a metal; this heat and light would become ſenſible. But the quantity of either diſengaged in any minute portion of time, is ſo ſmall as to be inſenſible, and the heat becomes confounded with that of the furnace. This diſengagement of caloric and light however is very ſenſible when bodies are calcined in pure oxygen gas. If a piece of iron be heated and plunged into this gas, it burns with great brilliancy, and becomes oxydated.

But though pure oxygen gas may be procured from oxids of mercury, merely by the action of heat, yet the oxyds of other metals cannot be reduced without the addition of ſome ſubſtance to which the oxygen has a greater affinity than to the metal. If charcoal be mixed with the metallic oxid, it will unite with the oxygen and form carbonic acid, which will fly off in the form of gas, while the metal will be reduced. Hence it is evident that the calcination of metals is nothing but their union with oxygen, and is therefore properly called their oxydation. This is very different from the theory delivered by Stahl, and ſupported by his followers.—They imagined metals to be compoſed of a certain earth which they called their calx, and phlogiſton; during the calcination they ſuppoſed the phlogiſton to be driven off, or diſſipated, and imagined that it could not be reſtored to them, or that they could not be revived, unleſs heated in contact with ſome ſubſtance which they ſuppoſed to contain phlogiſton. This theory was however attended with inſurmountable difficulties, and involved its advocates in continual abſurdities. The mere reduction of mercurial oxids by heat alone, is of itſelf ſufficient to overturn it.

The principal phenomena which take place when combuſtible bodies are heated in contact with air, are heat, motion, flame, and an entire change of the nature of the body burned. Some bodies burn with very great rapidity, others more ſlowly, and others without any apparent motion or flame. If combuſtion be performed in ſuch a manner that all the products formed by it can be preſerved and collected, theſe products are always heavier than the body which has been burned. It has been long known that combuſtion could not take place excepting atmoſpheric air was preſent, and it has been explained in various ways.

According to Lavoiſier's theory it appears, that combuſtion differs from the oxydation of metals, chiefly in its being more rapid; and in the products being many of them volatile inſtead of fixed. This analogy will lead to an eaſy explanation of combuſtion. If we conſider a familiar inſtance, the combuſtion of coal in a common fire, we ſhall find that it will be firſt neceſſary to apply heat, becauſe the combuſtible body is not diſpoſed to combine with oxygen, till the coheſion of its particles are diminiſhed by caloric. When this is done to a certain degree, the coal combines rapidly with oxygen, and during the combination, the oxygen gives out the heat and light which preſerved it in the form of gas. Though a great weight of coal is conſumed, and only a few aſhes left behind, yet if all the volatile products be collected, we ſhall always find them heavier than the coal was before combuſtion.

Oxygen gas contains a much greater quantity of combined caloric than any other ſubſtance with which we are acquainted; but carbonic acid gas has a much leſs capacity for heat than oxygen gas; when therefore oxygen gas combines with charcoal, part of its heat remains latent, and preſerves the carbonic acid which is formed in a gaſeous ſtate, while a conſiderable portion aſſumes the form of ſenſible heat.

From this theory of combuſtion, we are enabled to explain a variety of phenomena; for inſtance, why the direct light of the ſun puts out a fire; why a fire burns brighter in froſty weather, &c. When oxygen in the form of gas unites with a combuſtible body likewiſe in the form of gas, the combination is very rapid; and as the compound which is formed generally occupies much leſs ſpace than the two ſubſtances did, a vacuum will be formed; and the ſurrounding air ruſhing in from all ſides to repleniſh the vacuum, cauſes a very loud report.

LECTURE XI.

FROM what has been ſaid, it is evident that oxygen has a greater affinity for metals heated to a certain degree, than for caloric in conſequence of which all metallic bodies, except gold, ſilver, and platina, have the property of decompoſing oxygen gas, by attracting its baſe from the caloric with which it was combined. The affinity of combuſtible bodies for oxygen is greater than that of metals for the ſame ſubſtance, they therefore unite with it rapidly, and in combining with them, the oxygen gives out a great part of the light and caloric which ſupported it in the ſtate of gas. Though moſt combuſtible bodies require to be heated before they combine with oxygen, yet ſome of them have ſo ſtrong an attraction for it, that they will unite with it in the ordinary temperature of the atmoſphere.

The following laws may be deduced from what has been ſaid concerning combuſtion.

1. Combuſtion cannot take place without the preſence of oxygen.

2. In every inſtance of combuſtion there is an abſorption of oxygen.

3. In the products of combuſtion there is always an augmentation of weight, equal to the quantity of oxygen abſorbed.

4. In every inſtance of combuſtion, light and heat are diſengaged.

The phenomena of combuſtion may be diſtinguiſhed into three ſtates, ignition, inflammation, and detonation. The firſt takes place when the combuſtible body is not in an aeriform ſtate, nor capable of aſſuming that ſtate; the ſecond when the combuſtible body in the form of vapour, or gas, comes in contact with oxygen gas. The third is a ſudden inflammation, which occaſions a noiſe by the inſtantaneous formation of a vacuum. In the greateſt number of inſtances in which detonation takes place, this phenomenon is produced by the combuſtion of hydrogen gas with oxygen.

When we conſider the phenomena of reſpiration, we ſhall find them very analogous to thoſe of combuſtion. A candle will not burn, nor an animal live, in an exhauſted receiver. When a candle is confined in a given quantity of atmoſpheric air, it will burn only for a certain time; and on examining the air in which it has burned, the oxygen gas is found to be all extracted, nothing remaining but azotic gas, and a quantity of carbonic acid gas; in the ſame manner, if an animal be confined in a given quantity of atmoſpheric air, it will live only a ſhort time, and the air will have loſt its oxygen, nothing remaining but azotic and carbonic acid gas.

A candle will burn, and an animal live much longer in pure oxygen gas, than in the ſame quantity of atmoſpheric air.

From conſidering the phenomena attendant on reſpiration, we may lay down the following general propoſitions.

1. An animal cannot live unleſs it be ſupplied with oxygen.

2. All animals do not require air of the ſame

purity; birds require air of greater purity than man, or animals which live upon the ſurface of the earth; and thoſe animals which live principally under ground, or which paſs the winter in a torpid ſtate, require an air much leſs pure than other animals.

3. The mode of reſpiration is different in different animals.

The air which has ſerved for reſpiration is found to contain a mixture of azotic and carbonic acid gas, with a ſmall quantity of oxygen gas, and a conſiderable quantity of water is thrown off from the lungs in reſpiration.

From a variety of facts it appears, that oxygen gas is decompoſed in the lungs during reſpiration; a part of the oxygen unites with the iron contained in the blood, and converts it into an oxyd; another and greater portion unites with the carbon brought by the venous blood to the lungs, and forms carbonic acid gas, while another portion of the oxygen unites with the hydrogen brought in the ſame manner, and forms water.

A portion of this oxygen which unites with the iron and hydrogen, becomes fixed on theſe ſubſtances, and gives out the heat which ſupported it in a gaſeous ſtate, while the remainder forming, carbonic acid gas, which has a leſs capacity for heat than oxygen gas, gives out a part of its caloric. Thus reſpiration is the cauſe of a continual extrication of heat in the lungs, which being conveyed by the blood to all parts of the body, is a conſtant ſource of heat to the animal. We may therefore conſider reſpiration as an operation in which oxygen gas is continually paſſing from the gaſeous to the concrete ſtate; it will therefore give out at every inſtant, the heat which it held in combination.

Theſe facts enable us to explain the reaſon why an animal preſerves nearly the ſame temperature notwithſtanding the various changes which occur in the temperature of the ſurrounding atmoſphere, which enables the human body to bear viciſſitudes that would otherwiſe deſtroy it. They likewiſe enable us to account for the difference of heat in different claſſes of animals; their heat being always proportioned to the quantity of oxygen gas which they decompoſe.

Combuſtion and reſpiration are continually diminiſhing the quantity of oxygen contained in the atmoſphere; if therefore the wiſe author of nature had not provided for its continual reproduction, the air muſt ſoon become too impure to ſupport life; but vegetables abſorb water and carbonic acid gas, which ſubſtances they decompoſe, and appropriating the hydrogen of the former, and the carbon of the latter to their nouriſhment, exhale the oxygen gas in a very pure ſtate:—thus animals and vegetables work the one for the other, and by this admirable reciprocity, the atmoſphere is always kept ſufficiently pure, and the equilibrium of its component parts conſtantly maintained.

LECTURE XII.

IN the laſt lecture it was hinted, that part of the oxygen received into the lungs, combined with the *iron* which exiſts in the blood; and it will not perhaps be improper to examine this idea more accurately.

That iron exiſts in the blood, may be proved from a variety of circumſtances; and particularly by the chemical analyſis of that fluid. This iron may be conveyed into the blood, by the articles of food, moſt of which contain ſome portion of this metal, though ſmall; but it is more probable that the greateſt part of the iron found in this fluid, is the product of animal organization; indeed ſeveral facts may be produced, that ſeem to ſhow, that the greateſt part of the iron which exiſts in nature, has been formed by vegetable and animal proceſſes.

It appears likewiſe that the red colour of the blood depends upon the oxydation of this iron, which that fluid contains in a ſtate of extreme diviſion. If the coagulable lymph and ſerum be carefully freed from the red particles by waſhing, the ſtricteſt analyſis will not diſcover in either of them a particle of iron, while the red particles thus ſeparated, conſiſt almoſt entirely of this metal.

That the red colour of the blood depends upon the combination of its ferruginous particles with oxygen, appears from the beautiful experiments of Menghini, Thouvenel, Prieſtley, &c.

It ſeems moſt probable, that the blood, during its circulation through the lungs, becomes combined with oxygen; that this oxydated blood, on its return to the heart, is circulated by the arteries to all parts of the body; and that during this circulation, its oxygen is extracted from it, by thoſe parts of the body with which it comes in contact: it is then brought back to the heart by the veins, of a dark colour, and deprived of the greateſt part of its oxygen. The effects of oxygen on the blood are well illuſtrated by what takes place while an animal is drowning. The oxygen is gradually ſubtracted from the blood, during its circulation, and there being no means by which that fluid can recover this principle, its colour gradually becomes darker, till both the arterial and venous blood is become almoſt black. Along with this abſtraction of oxygen, the animal becomes more and more feeble, and in a few minutes dies. If immediately before death, the lungs be laid open, that we may obſerve what takes place, and if a quantity of oxygen gas be injected through the windpipe, we immediately ſee that the blood acquires a red colour, and circulates towards the heart; which organ, as ſoon as the oxydated blood arrives at it, recovers its irritability, and by contracting, circulates the blood as uſual.

Hence it would ſeem, that the production of animal heat is not the moſt important office of reſpiration; for it is not improbable that irritability, or the vital principle, is continually communicated to the body by theſe means.

That this is the caſe would appear from ſeveral experiments made by Dr. Girtanner, and from the accurate obſervations of Lind and Trotter, on the caſes of ſcorbutic patients, as well as the *blue boy* mentioned by Dr. Sandifort; in all which it appears, that a diminution of oxygen is accompanied by a diminution of irritability, or excitability, and that this irritability is reſtored by reſtoring the oxygenous principle.

How multiplied and important are the parts acted by this principle on the theatre of nature! When combined with hydrogen, it forms water; in its union with combuſtible bodies, it gives out heat and light, without which we ſhould not be able to perform the moſt important operations of life: it likewiſe forms different acids of the greateſt utility in the arts. When received by animals into the lungs, it is the cauſe of their heat, and ſupplies them with irritability.

The irritability thus ſupplied by the lungs, is continually waſted by muſcular exertion, and the action of different ſtimuli. This has been ingeniouſly ſhown by Dr. Brown, and as it is a ſubject of great importance in the philoſophy of living matter, it may not be improper to point out ſome of the laws by which living bodies are governed.

I. Living bodies, beſides their organization, differ from dead matter, in the property of being acted on or excited by external powers, in ſuch a manner as to produce the living functions; they muſt therefore poſſeſs ſome property diſtinct from dead matter, which renders them capable of being thus acted on by external powers.—This property has been called *excitability*, or *irritability*.

II. When the powerful action of the exciting powers ceaſes for ſome time, the excitability accumulates, or becomes more capable of receiving their action, and is more powerfully affected by them. If the action of the different exciting powers which ſupport life be examined, we ſhall find abundant confirmation of this law. If light, heat, food, &c. be withdrawn for ſome time, they act much more powerfully when applied again.

III. When the exciting powers have acted with violence, or for a conſiderable time, the excitability becomes exhauſted, or leſs fit to be acted on. The truth of this law may be proved by a ſimilar induction.

This exhauſtion of the excitability may be either finite, or temporary. When the exciting powers are continually and violently applied, they entirely exhauſt the excitability, and produce death; but we find that this principle may be exhauſted for a time, and accumulated again. When we have been engaged in any exertion, either mental or corporeal, for ſome hours only, we find ourſelves fatigued, and unfit to purſue our labours much longer; if now ſome of the exciting powers be withdrawn, and if we are laid in a poſture which does not require much muſcular exertion, we ſoon fall into that ſtate which nature intended for the accumulation of excitability, and which we call ſleep. In this ſtate many of the exciting powers cannot act upon us, unleſs applied with ſome violence, and we are inſenſible of their moderate action.

When the action of theſe powers has been ſuſpended for ſix or eight hours, the excitability is again capable of being acted on, and we riſe freſh and vigorous, and fit to engage in our occupations.

From what has been ſaid, it is evident, that there are three ſtates in which living bodies exiſt.—1. A ſtate of accumulated excitability.—2. A ſtate of exhauſted excitability.—3. When it is in ſuch a ſtate as to produce the ſtrongeſt and moſt healthy actions, when acted on by the external powers. It appears likewiſe, that life depends on the action of external powers on the excitability; and that by their continued action, if they be properly regulated.

ed, the excitability will be gradually, and as it were inſenſibly exhauſted, and life will be reſigned into the hands of him who gave it, without a ſtruggle, and without a groan. But as it often happens that we have not the power of regulating the action of theſe powers, and frequently neglect it when we have; thoſe deviations from the third ſtate, called diſeaſes, take place, which it is not our buſineſs to conſider in this courſe of lectures.

LECTURE XIII.

HYDROGEN, combined with caloric, forms hydrogen gas; this ſubſtance, which was formerly called inflammable air, was diſcovered by Mr. Cavendiſh in the year 1767. Its baſe is called hydrogen, becauſe it is one of the component parts, or more properly the baſe of water. It may be procured from ſeveral ſubſtances, of which it forms a conſtituent part, but is obtained in the moſt pure ſtate from the decompoſition of water by means of metals.

Metallic ſubſtances will not decompoſe water while cold, unleſs aſſiſted by an acid, in which caſe the water is very readily decompoſed; its oxygen, oxydating the metal, and the hydrogen flying off in the form of gas.

M. Lavoiſier has proved, that when 85 parts of oxygen gas are burned with 15 of hydrogen gas, both gaſes vaniſh, and 100 parts of water are formed; and if 100 parts of water are made to paſs through a red hot iron tube, 15 parts of hydrogen gas will be procured, while the inſide of the tube will be found converted into an oxyd, and to have gained 85 parts in weight.

Hydrogen gas is combuſtible in an eminent degree; yet it will not burn, unleſs in contact with oxygen. When pure, and in contact with atmoſpheric air, it burns with a lambent flame. It burns rapidly when intimately mixed with atmoſpheric air, in ſuch a manner that each particle of hydrogen gas may be ſurrounded by particles of atmoſpheric air. Fire works without ſmoke or noiſe, are made by means of hydrogen gas. It is about twelve times lighter than common air, and on this property depends the principles of aeroſtation. Charcoal, when ignited, will decompoſe water, but the hydrogen gas procured in this manner is never pure, being always mixed with carbonic acid gas. Theſe gaſes, though poſſeſſed of very different ſpecific gravities, do not eaſily ſeparate from each other, but form by the attraction of their particles, a compound elaſtic fluid called hydrocarbonic gas. It is this aeriform fluid which floats frequently on marſhes, and being ſet on fire by electricity, or other means, gives riſe to the *ignis fatuus.*

Hydrogen gas is improper for reſpiration. An animal immerſed in it is killed in the ſame manner as when immerſed in azotic gas. This however does not ſeem to depend upon any poſitive noxious quality which this gas poſſeſſes, but merely on its excluding oxygen gas. When hydrogen gas is mixed with about one-third of its quantity of oxygen gas, it may be breathed without inconvenience.

Hydrogen gas is frequently found in great abundance in coal mines; where it is ſometimes generated ſuddenly, and becomes mixed with the atmoſpheric air of theſe ſubterraneous cavities. If a lighted candle be brought in, this mixture often explodes in the moſt violent manner. It is called by miners the fire-damp. Methods have however been contrived to prevent its dreadful effects.

Hydrogen gas is capable of diſſolving ſome combuſtible bodies, particularly ſulphur and phoſphorus; and when united to theſe, it ſeems to acquire new properties. When united to ſulphur it forms ſulphurated hydrogen gas, or that fluid which is contained in conſiderable quantity in ſulphurous mineral waters. This gas blackens metallic ſubſtances, is very ſoluble in water; is unfit for reſpiration; and turns vegetable blues green.

The union of hydrogen gas and phoſphorus is called phoſphorated hydrogen gas. This elaſtic fluid has a very fœtid ſmell, is improper for reſpiration, and takes fire ſpontaneouſly on coming in contact with the air, accompanied with an exploſion. It is probably to a diſengagement of gas of this kind, that we ought to attribute the *ignes fatui* which play about burying grounds, and in general about places where animals are putrifying.

There is probably a ſtratum of hydrogen gas in the ſuperior regions of the atmoſphere, the union of which with oxygen will form water, and may produce meteors.

LECTURE XIV.

WE have ſeen that the atmoſphere is compoſed of two gaſes or elaſtic fluids, the firſt which is called oxygen gas, conſtitutes nearly one-fourth of the atmoſphere; the latter about three-fourths. The firſt is compoſed of light, caloric, and oxygen; the latter alſo is compoſed of caloric, and a particular baſe, capable of becoming ſolid, called azote.— This ſubſtance united to different baſes, forms alkalies, and hence may be looked upon as a real alkaligen, or alkalizing principle, in oppoſition to oxygen, which is the principle of acidity. The atmoſphere therefore is an immenſe reſervoir of the principles of acidity and alkaleſcency, without being itſelf either acid or alkaline.

Azotic gas may be obtained pure by various means; particularly by expoſing certain ſubſtances to atmoſpheric air, which abſorb its oxygen. As it has been proved that azote united with hydrogen forms ammoniac, or the volatile alkali, and as it is highly probable that the other alkalies are compoſed of earthy baſes united to this ſubſtance, it will be neceſſary here to conſider the properties of the different alkalies.

The general properties of alkalies are the following:

1. Their taſte is acrid, burning, and urinous.

2. They change the blue colours of ſome vegetable infuſions to green.

3. When mixed with flinty ſubſtances, and expoſed to a conſiderable heat, they form glaſs.

4. They render oils miſcible with water; efferveſce with ſome of the acids, and form neutral ſalts with all of them.

Alkalies are divided into fixed and volatile.—There are two ſpecies of fixed alkali: the vegetable alkali, or potaſh, and the mineral alkali or ſoda.—The vegetable alkali may be extracted from various ſubſtances, but chiefly from the aſhes of vegetables and tartar; when purified, it is generally known under the name of ſalt of tartar.

The mineral alkali, or ſoda, is the baſe of ſea ſalt. It may be procured from this ſalt by various means, but is moſt uſually procured from the aſhes of marine plants. This alkali differs from the vegetable in the following particulars.—1. It is leſs caustic.—2. It effloreſces in the air inſtead of attracting moiſture from it.—3. It forms octoedral inſtead of quadrangular cryſtals.—4. It forms different neutral ſalts with the ſame acids.

Theſe alkalies, in the ſtate we generally meet with them in commerce, are not pure, but really neutral ſalts, being combined with the carbonic acid; and it is only by a particular management that we can procure them in a pure and uncombined ſtate. The carbonic acid may be ſeparated from them, by preſenting to them any ſubſtance which has a ſtronger attraction for that acid.—The alkalies thus freed from carbonic acid are ſaid to be cauſtic. In this ſtate they unite readily with fats and oils, and form ſoap. The fixed alkalies combine with ſulphur by fuſion, and form ſulphurets. Theſe alkaline ſulphurets diſſolve metals, even gold itſelf.

From the experiments of Thouvenel and Chaptal, on the formation of nitre, as well as ſome others lately made with the oxygenated muriat of potaſh, there is reaſon to conclude that the combination of azote with lime, forms potaſh, while its union with magneſia forms ſoda.

The volatile alkali, or ammoniac, is diſtinguiſhed from the fixed alkalies, by its penetrating odour, and remarkable volatility. This alkali is obtained in great abundance from animal ſubſtances, and particularly from the horns: but the greateſt part of the volatile alkali in uſe is produced from the decompoſition of ſal ammoniac, or the muriat of ammoniac, by diſtilling this ſalt in contact with ſome ſubſtance, which by its ſuperior affinity diſlodges the volatile alkali from the muriatic acid. When quicklime is uſed for this purpoſe, the volatile alkali is obtained in the form of gas and cauſtic. From ſeveral experiments made by M. Bertollet and Dr. Auſtin, it has been proved that ammoniac is compoſed of hydrogen and azote. According to the analyſis of the former, 1000 parts of ammoniac are compoſed of 807 of azote, and

193 of hydrogen. Azote combined with oxygen forms the nitric acid, but before we examine its nature, it will be beſt to take a view of the general properties of acid bodies, which will be found to be the following—

1. They excite a particular ſenſation on the palate which we call ſour.

2. They change the blue colours of vegetables into red.

3. All of them, excepting the carbonic acid, effervefce with the mild alkalies.

M. Lavoiſier has proved, by an accurate analyſis of the greater part of known acids, that oxygen forms the principle of all, and that their difference from each other depends on the ſubſtance combined with the oxygen. The adheſion of oxygen to the baſe is more or leſs ſtrong in different acids, in conſequence of which they are more or leſs eaſily decompoſed.

It has been proved both by analyſis and ſyntheſis, that the nitric acid is compoſed of four parts of oxygen, and one of azote, chemically combined.

This acid corrodes and diſſolves with great avidity copper, iron, zinc, tin, and ſome other metals; and in theſe operations becomes decompoſed; its oxygen oxydates the metal, while the azote, ſtill combined with a ſmall portion of oxygen, forms nitrous gas, or gaſeous oxyd of azote.

This acid is never found pure, but always in a ſtate of combination, moſt commonly with potaſh, forming nitrat of potaſh, or common nitre. From this ſalt it is extracted for uſe, by means of the ſulphuric acid, which diſloges the nitric acid from the alkali, by its greater affinity. What remains in the retort is ſulphat of potaſh; the nitric acid paſſes over into the receiver, and is purified if neceſſary by various means.

LECTURE XV.

NITRIC acid acts powerfully on inflammable and metallic ſubſtances, and during this action it becomes decompoſed; a part of its oxygen unites with the inflammable ſubſtance, while the azote, united to a ſmaller portion of oxygen, flies off in red fumes, which may be received under a pneumatic apparatus, being the gaſeous oxyd of azote, or what has been generally called nitrous gas. This gas is ſomewhat lighter than common air, and is improper for reſpiration and combuſtion. Oxygen gas combines with it very rapidly, converting it into nitric acid; atmoſpheric air produces the ſame effect, but more ſlowly. This combination of oxygen and nitrous gas, preſents many important and intereſting phenomena. The more pure the air is, the more rapid and remarkable are theſe phenomena; and on this principle has been contrived an eudiometer,

meter, or inſtrument for aſcertaining the purity of the atmoſphere. When azote is combined with a ſmall portion of oxygen, it forms this gas, when more oxygen is added, it forms the fuming nitrous acid, and when fully ſaturated with this principle, nitric acid is produced.

Nitric acid combines with various ſubſtances, forming ſalts, which are called nitrats: thoſe formed by the nitrous acid being called nitrites. The moſt important combination is the nitrat of potaſh, or common nitre. This ſalt is produced in conſiderable quantity in many parts of the world, by expoſing putrifying animal ſubſtances in contact with lime. The lime uniting with the azote of the animal ſubſtance, probably forms potaſh; and the combination of the azote from the ſame ſource, with the oxygen of the atmoſphere, produces nitric acid. A conſiderable part however of the nitric acid thus formed, is combined with lime, which baſe is exchanged for an alkaline baſe to convert it into nitre. It is afterwards purified by ſolution and cryſtallization.

When nitrat of potaſh is diſtilled in a red heat, 12000 cubic inches of oxygen gas may be procured from a pound of it. One hundred parts of this ſalt are compoſed of thirty of nitric acid, ſixty-three of potaſh, and ſeven of water.

If ſeventy-five parts of nitre, nine and a half of ſulphur, and fifteen and a half of charcoal, be mixed together, it forms gunpowder; the effects of which depend on the rapid and inſtantaneous decompoſition of the nitre, and the combuſtion of the ſulphur and charcoal by means of its oxygen.

The nitric acid combined with the mineral alkali forms nitrat of ſoda, and with ammoniac, nitrat of ammoniac; ſalts which are not much known.

Charcoal is placed among the elementary bodies, becauſe we have not yet by any means been able to decompoſe it. It forms the ſkeleton of vegetables, or their woody fibre. The microſcope diſcovers a ſurprizing number of pores in charcoal, Dr. Hook calculated that a piece of charcoal of an inch in diameter, contains no leſs than 5,724,000 pores. It is to this poroſity that the blackneſs of charcoal is owing, and through theſe pores the vegetable juices circulate.

Charcoal is very incorruptible, and on that account, the lower parts of poſts uſed in paling, are charred to preſerve them.

The charcoal is procured by heating wood in ſo ſlow a manner that the oily and watery parts are driven off in vapour, while the carbon, which cannot be reduced to vapour by heat, remains, preſerving the exact form of the vegetable.

The very light charcoals of linen, cotton, and ſome fungi, readily catch fire from a ſpark; theſe ſubſtances are called tinder. Charcoal is much uſed in chemiſtry, and in ſeveral of the arts. It is one of the moſt powerful antiſeptics with which we are acquainted. Hence, it preſerves water from putrefaction, and reſtores its ſweetneſs, after it has become putrid. It preſerves meat, and will render brown rancid oils ſweet and clear, which effects are produced by its ſtrong affinity for oxygen.

If by any means, large quantities of vegetable matters are buried at ſome depth under ground, or kept for a long time from contact with the atmoſphere, the aqueous and oily parts will be diſſipated, and the vegetable fibre will remain in the form of of a charcoal, mixed with more or leſs ſulphur, which is contained in all vegetables. The immenſe quantity of leaves, and other vegetable matters that are continually waſhed down rivers, will be collected in beds at the bottom of the ſea, and there become charred; and being reduced into a minute ſtate by attrition, and other circumſtances, inſtead of preſerving the appearance of vegetables, they reſemble foſſils, and form beds of coal.

LECTURE XVI.

WHEN charcoal is burned in a quantity of oxygen gas, exactly ſufficient for its combuſtion, both the charcoal and oxygen gas diſappear, and a quantity of elaſtic fluid is found in the veſſel, which is equal in weight to both the charcoal and oxygen gas.

This elaſtic fluid is manifeſtly acid, and being compoſed of carbon and oxygen, it is called in the new Nomenclature, the carbonic acid. We are indebted to Dr. Black for our knowledge of ſome of the moſt remarkable properties of this fluid; he was the firſt who diſcovered the affinity between this gas and alkalies, quicklime, and magneſia.

This ſubſtance has received different names from different chemiſts. Dr. Black called it fixed air, which Macquer obſerves is by no means a proper name for it; he called it mephitic air, but this is not by any means peculiarly characteriſtic. Bergman called it aerial acid, and it has likewiſe been called the cretaceous acid, or acid of chalk, becauſe it is contained in large quantity in that ſubſtance.

This acid exiſts in three different ſtates; in a ſtate of combination, in the ſtate of gas, and in that of mixture. It is combined with calcareous earth or lime, for which it has a greater affinity than for any other. It conſtitutes nearly half the weight of chalk, limeſtone, marble, &c. converting them into ſaline ſubſtances or carbonats. It may be procured from theſe ſubſtances by two different methods, namely, by heat, or the affuſion of acids. The firſt is done in burning lime; the carbonic acid combines with caloric, and flies off in the form of gas, leaving the calcareous earth pure. If a quantity of chalk be put into a retort, and ſulphuric acid poured upon it; the carbonic acid may be expelled in the form of gas, and is found to be poſſeſſed of the following properties. Firſt, it extinguiſhes flame, and kills animals immerſed in it. Second, its ſpecific gravity is much greater than that of common air, on this account it occupies the loweſt part of the atmoſphere, and may be poured out of one veſſel into another like water.

This gas is emitted in large quantities by fermenting liquors, being often generated plentifully in coal mines, and is inſtantly fatal to the miners, who call it the choak, or chalk damp. Wells which have been long ſhut up, are often found filled with this gas, and therefore workmen ſhould never enter them without proper precautions. There are methods however by which both coal pits and wells may be purified.

There are ſome natural caverns in which this gas is produced in conſiderable quantity, and runs out at the opening like a ſtream of water; this is particularly the caſe with the celebrated grotto *del cano.*

Charcoal ſhould never be burned in rooms that have no fire place, or vent, becauſe the red hot charcoal unites with the oxygen of the atmoſphere, and forms carbonic acid, which cannot eſcape without a ventilator. Some melancholy accidents have happened from this cauſe.

Water abſorbs more than its bulk of this gas at a mean temperature, and acquires an acid taſte, and ſparkling appearance, like ſome of the mineral waters. Various methods have been contrived for impregnating water with this gas, but the machine invented by Dr. Nooth, is by much the moſt convenient and elegant. Moſt mineral waters owe their ſharp ſpirituous taſte to this gas. Water thus impregnated is capable of diſſolving a ſmall quantity of iron, and forms an elegant chalybeate, ſimilar to ſome of the natural chalybeates. When fixed alkali is previouſly diſſolved in water, it will then abſorb a much greater quantity of carbonic acid than common water, forming the aqua mephitica alkalina, which is ſo uſeful in calculous complaints. This is likewiſe the beſt way of giving effervefcing draughts. Carbonat of lime cannot be diſſolved in water, except in very ſmall quantity, but pure lime can be diſſolved in conſiderably greater weight, forming lime water, which is an excellent teſt of the preſence of carbonic acid; for it is inſtantly precipitated by that acid in the form of carbonat of lime. By this mean we alſo prove that the air which comes from the lungs contains carbonic acid.

But though water will only diſſolve a very ſmall portion of carbonat of lime, yet if the water be ſaturated with carbonic acid, it will then diſſolve carbonat of lime in conſiderable quantity. If this ſolution be let fall, drop by drop, on any ſubſtance, as the carbonic acid eſcapes, the carbonat of lime will be depoſited upon the ſubſtance, which will in this manner become encruſted with a coat of calcareous earth. In this ſtate the ſubſtance has been called petrified.

Cyder, beer, and other fermented liquors, owe their briſkneſs to the carbonic acid which they contain.

Many chemiſts ſuppoſed that carbonic acid was compoſed of vital air and phlogiſton; but as the ſcience of chemiſtry advanced, it was proved by Lavoiſier, that the charcoal of wood combined with vital air, and formed carbonic acid. With this ſynthetic proof the French chemiſts were contented; it was afterwards demonſtrated analytically by Dr. Tennant, who ſhowed that charcoal and phoſphoric acid were produced, by applying phoſphorus to red hot marble; from which he inferred, that the carbonic acid of the marble was decompoſed; its oxygen uniting with the phoſphorus, formed phoſphoric acid, while the carbon was left uncombined.

LECTURE XVII.

SULPHUR is a very combuſtible ſubſtance, dry, brittle, and of a fine yellow colour. It has no ſmell excepting it be warmed, when it ſends forth a peculiar though weak odour. If it be rubbed it becomes electrical, and a roll of ſulphur graſped in the hand, breaks with a crackling noiſe.

Sulphur is found in great quantity in nature, ſometimes in a ſtate of purity, but moſt commonly combined with ſome of the metals. It is frequently formed by the decompoſition of animal and vegetable ſubſtances; and particularly where large quantities of vegetables are putrefying.

A moderate degree of heat is ſufficient to melt ſulphur, and if at the inſtant when its ſurface begins to congeal, the liquid ſulphur under the ſurface be poured into another veſſel, it will form cryſtals.

Sulphur unites with moſt of the metals, and renders them very brittle and fuſible: moſt of the imperfect metals are indeed found combined with ſulphur, or mineralized by it, as it is termed; the metal is freed from the ſulphur by roaſting, before it is ſmelted. Sulphur unites with iron when that metal is red hot, and forms a hard compound; and this furniſhes us with an eaſy and excellent way of faſtening pieces of iron in ſtone.

Sulphur, like all combuſtible bodies, only burns in proportion to the quantity of oxygen which combines with it; and the products of this combuſtion vary according to the proportion of oxygen combined with the ſulphur; if only a ſmall quantity of oxygen be combined with it, a volatile and penetrating acid is formed, called *ſulphurous* acid; but if the combuſtion be carried on rapidly, ſo that a greater quantity of oxygen may be combined with the ſulphur, a ponderous acid is formed called the *ſulphuric.*

The characters of this acid are the following, Firſt, it is unctuous and greaſy to the touch. Second,

cond, its ſpecific gravity is much greater than that of water. Third, when mixed with an equal quantity of water, a degree of heat is produced greater than that of boiling water.

Concentrated ſulphuric acid expoſed to cold, concretes, and may be obtained in a cryſtalline form. The ſulphuric acid is uſed in ſeveral of the arts and manufactures.

This acid united to potaſh, forms a neutral ſalt called ſulphat of potaſh. One hundred parts of this ſalt contain thirty of acid, ſixty-five of alkali, and five of water.

This acid combined with the mineral alkali forms ſulphat of ſoda, which may be procured in beautiful cryſtals, and is commonly known by the name of Glauber's ſalt. One hundred parts of this ſalt contain fourteen of acid, twenty two of alkali, and ſixty-four of water. With the volatile alkali, the ſulphuric acid forms a neutral ſalt, called the ſulphat of ammoniac, which cryſtallizes with difficulty, and is little known.

LECTURE XVIII.

PHOSPHORUS is one of the moſt curious ſubſtances in chemiſtry; the diſcovery of it is attributed by Leibnitz to Brandt. He made this diſcovery in the year 1667, and communicated it to Kraft, who imparted it to Mr. Boyle.

It appears that Kunckel and Kraft had agreed to purchaſe the ſecret from Brandt, but Kunckel having been deceived by Kraft, fell to work himſelf, and diſcovered a way of making this ſubſtance, which he publiſhed, and from that time it has generally gone by his name.

For ſome time phoſphorus was made in very inconſiderable quantities, the operation being tedious and diſagreeable, conſiſting in evaporating large quantities of urine. Various methods were taken to ſhorten the operation, and render the proceſs leſs diſagreeable, but to little purpoſe; the beſt account of this method of making phoſphorus was publiſhed by Margraff, in the Berlin Memoirs.

In 1769, Monſieur Gahn diſcovered, that the earth which remains after the calcination of bones, conſiſts of phoſphat of lime, and Scheele proved, that by mixing this phoſphat of lime with the nitric or ſulphuric acids, theſe acids, by their ſuperior attraction, combined with the lime, and expelled the phoſphoric acid; and by diſtilling this acid with powdered charcoal, he obtained phoſphorus. The proceſs is very well deſcribed in Chaptal's elements of chemiſtry.

Since this time, phoſphorus has generally been extracted from the earth of bones, and the making of it is by no means ſo difficult an operation as formerly.

In whatever manner phoſphorus is made, it is always the ſame ſubſtance. It is generally of a fleſh colour, and tranſparent when pure; is of the conſiſtence of wax, and may be cut with a knife.— When it comes in contact with the air it emits a white ſmoke, and its ſurface appears luminous in the dark. When expoſed to the atmoſphere, and heated to about 86 degrees of Fahrenheit's ſcale, it takes fire, and burns with great rapidity; what remains after the combuſtion is of a red colour, attracts humidity from the air, and becomes liquid: this liquid is the phoſphoric acid which will ſoon be noticed.

If we write with phoſphorus upon any ſolid body, the characters become luminous in the dark.—Various contrivances have been made for lighting a candle by means of phoſphorus, ſuch as the philoſophical fire-bottles, and phoſphoric bougies; but the phoſphoret of lime ſeems beſt to anſwer this purpoſe.

Phoſphorus is capable of being diſſolved by various liquids; ſuch as alcohol, ether, and oil, which it renders luminous. The phoſphoric oil, or liquid phoſphorus, as it is generally called, may be rubbed upon any part of the body without danger, and renders that part luminous in the dark. The light produced by this ſolution of phoſphorus in oil, very much reſembles that of the glow-worm.

Putrifying animal ſubſtances generally emit a phoſphoric light, and particularly fiſh; rotten wood often does the ſame.

If phoſporus be heated to about 84 degrees, and plunged in pure oxygen gas, it burns with great brilliancy; during this combuſtion the oxygen is abſorbed, and a quantity of acid liquor formed, which is equal in weight to the quantity of oxygen and phoſphorus conſumed. Lavoiſier, and De la Place, have found that forty-five grains of phoſphorus, during their combuſtion, abſorb ſixty-five grains of oxygen.

Phoſphorus unites with oxygen in three different ways. Firſt, by a rapid combuſtion and deflagration. Second, by a ſlow combuſtion. Third, by a decompoſition of bodies which contain oxygen.

The phoſphoric acid combines with a variety of ſubſtances, particularly lime, and the alkalies.—With lime it forms phoſphat of lime, or earth of bones, which is ſometimes found in nature in large quantities; entire rocks being compoſed of it.—With potaſh this acid forms a ſalt capable of chryſtallization, called phoſphat of potaſh, which is very little known. With ſoda it forms a ſalt, which may be procured in beautiful cryſtals, called phoſphat of ſoda, but better known by the name of taſteleſs purging ſalt; it is chiefly uſed as a laxative.

Phoſphoric acid unites with ammoniac, and forms phoſphat of ammoniac, a ſalt which is ſometimes found in putrifying animal ſubſtances, but is very little known.

LECTURE XIX.

THE muriatic acid, or ſpirit of ſalt, as it is commonly called, is very abundant in the mineral kingdom, being naturally combined with different baſes, particularly with ſoda, lime, and magneſia. This acid is never found pure or uncombined, and in order to obtain it in this ſtate, we muſt diſengage it from other ſubſtances, with which it is in combination. It is moſt uſually diſengaged from common ſalt, by means of the ſulphuric acid, which having a greater affinity for the ſoda, the muriatic acid is expelled in the form of gas, and is abſorbed by the water in the receiver. Wolfe's apparatus is the beſt for this purpoſe.

Though in the new Nomenclature, the muriatic radical is put down among the acidifiable baſes, yet the muriatic acid does not appear to have been decompoſed in any chemical experiment: ſo that we have no idea whatever of the nature of this radical, and only conclude from analogy that oxygen is its acidifying principle.

The muriatic acid is more light and volatile than the ſulphuric, and has a weaker affinity for earths and alkalies. It differs from the nitric acid in its colour, being of a yellowiſh green, while the latter is generally of an orange colour.

The muriatic acid combines with potaſh, and forms a ſalt called muriat of potaſh, formerly known by the name of febrifuge ſalt of Silvius. The cryſtals of this ſalt are not cubic, like common ſalt, but parallelopepids. One hundred grains of this ſalt contain thirty of muriatic acid, ſixty-four of potaſh, and ſix of water.

The muriatic acid forms with ſoda a neutral ſalt called muriat of ſoda; this combination is the common alimentary ſalt, the taſte of which is well known: it decrepitates when thrown upon hot iron, and is nearly equally ſoluble in cold and hot water. One hundred parts of this ſalt contain thirty-four of acid, fifty of alkali, and ſixteen of water. The figure of its cryſtals is perfectly cubic. It is uſually procured from ſea-water, and ſalt-ſprings, and exiſts in various parts of the world in the form of foſſil or rock ſalt. This ſalt is of three kinds, namely, rock, or native ſalt, bay ſalt, and white ſalt. The firſt is dug out of mines, the ſecond is procured from ſea water evaporated by the ſun, and to obtain the laſt, ſea water is evaporated by boiling.

The muriatic acid combines with the volatile alkali or ammoniac, forming the muriat of ammoniac. This is the moſt uſeful and intereſting of all the combinations with ammoniac, and is known by the name of crude ſal ammoniac. This ſalt is much uſed in the different arts, and has the property of making tin unite very readily with iron and copper. It is uſually brought from Egypt in ſemi-tranſparent cakes, but ſome manufactories of it have lately been eſtabliſhed in Europe, theſe have however been kept ſecret. One hundred parts of this ſalt contain fifty-two of acid, forty of ammoniac, and eight of water.

This ſalt may be decompoſed both by acids and alkalies; the ſulphuric and nitric acids unite with the ammoniac, and diſengage the muriatic acid. The fixed alkalies and lime have a greater affinity for the muriatic acid than the ammoniac has, and will therefore decompoſe this ſalt.

The muriatic acid is capable of combining with a much greater quantity of oxygen than it poſſeſſes in the ſtate of common muriatic acid, and what is remarkable, it becomes more volatile, while the other acids, when ſuper-oxygenated, become more fixed. In this ſtate likewiſe its powers as an acid are weakened, for it has a much weaker affinity for alkaline ſalts, and will not even redden the blue colours of vegetables, on the contrary, it deſtroys theſe colours. The acid in this ſtate is called the oxygenated muriatic acid. The muriatic acid ſeizes oxygen with great avidity, yet ſo weakly does it hold it in union, that it may be expelled by a very moderate degree of heat, or even by expoſure to the rays of the ſun. This acid is procured by diſtilling common muriatic acid from the oxyd of manganeſe, by means of Wolfe's apparatus; the acid attracts the oxygen of the manganeſe, and flies off in the form of gas, which is readily abſorbed by water.

When oxygenated muriatic acid is mixed with cauſtic or pure ammoniac, a quantity of water is formed, and azotic gas is diſengaged, the acid returning to the ſtate of common muriatic acid. In this experiment the oxygen of the acid combines with the hydrogen of the ammoniac, and forms water.

The oxygenated muriatic acid forms with potaſh a beautiful white ſalt called the oxygenated muriat of potaſh. The oxygenated muriatic acid which exiſts in this ſalt, contains much more oxygen than when in a liquid ſtate, and the oxygen is very looſely attached, being ſeparable by mere heat. From one hundred grains of this ſalt may be procured ſeventy-five cubic inches of extremely pure oxygen gas. A ſmall quantity of this ſalt rubbed in a mortar with flowers of ſulphur, explodes, and ſtill more violently with phoſphorus.

If this ſalt be uſed inſtead of nitre, a gunpowder will be formed much more powerful it its effects than common gunpowder.

If the muriatic acid be combined with the nitric, an acid is formed, which has different properties from either of its component parts; this acid is called in the new Nomenclature the nitro-muriatic acid, and was formerly known by the name of aqua regia.

Berthollet thinks, that in this caſe the acidifyable baſes combine, and form a ſingle acid different from all others; but Chaptal is of opinion, that in this operation the muriatic acid becomes oxygenated by ſeizing the oxygen of the nitric acid, and this on ſeveral accounts ſeems moſt probable.

LECTURE XX.

THE principal vegetable acids are the acetous and the tartarous; the former is known by the name of vinegar, and is formed by the oxydation of vinous liquors, generally by expoſing them to the atmoſphere. It appears in the form of an acid liquor, more or leſs deeply tinged; by diſtillization it is ſeparated from its impurities, and is then tranſparent and colourleſs; when concentrated, which it may be by various methods, it is called radical vinegar. The acetous acid produces neutral ſalts by combining with different ſubſtances. With potaſh it forms acetite of potaſh, commonly called diuretic ſalt, which may be procured in fine cryſtals, but is very deliqueſcent. The acetite of ſoda is likewiſe deliqueſcent, but very little known. The acetite of ammoniac is extremely deliqueſcent, and is known in medicine by the name of ſpirit of Mindererus.

The radical of the acetous acid is carbon, hydrogen, and a little azote.

Several vegetables, as lemons, ſorrel, and unripe fruit, contain acids ready formed by nature, which conſiſt, like the acetous acid of compound radicals, differing only in the proportions of thoſe ſubſtances which compoſe the radical. Theſe acids may be concentrated by freezing.

Sugar, and the farinaceous vegetables, conſiſt of hydrogen, carbon, and a little oxygen. If theſe ſubſtances be combined with more oxygen, an acid may be procured in cryſtals reſembling the acetous acid in taſte, but differing from it in ſome other properties. This acid is called acid of ſugar, or oxalic acid, and is generally made by oxydating ſugar by means of the nitric acid.

The acid of ſugar unites with alkalies, earths, and metals, and gives the name of oxalat to the combination. The moſt curious fact relative to this acid is, that it attracts lime more powerfully than any other acid, forming with it a compound nearly inſoluble; on this account it is an excellent teſt of the preſence of lime. The acid of ſugar takes ſpots, and particularly iron-moulds, out of linen. The mallic and citric acids are only varieties of this acid.

Wood, when burned or diſtilled, yields a particular acid, called the pyroligneous acid, which is uſed by callico printers to diſſolve iron.

If tartar be diſſolved in water by boiling, and the clear liquor ſuffered to cryſtallize, beautiful cryſtals may be procured, which have been called cream, or cryſtals of tartar, but according to the new Nomenclature, acidulous tartarite of potaſh, for they conſiſt of potaſh ſuper-ſaturated with a particular acid called the tartarous.

The acidulous tartarite of potaſh is capable of combining to ſaturation with potaſh, and forms a neutral ſalt, the tartarite of potaſh, which has commonly been called Rochelle ſalt.

The radical of the tartarous acid is like other vegetable acids, compoſed of hydrogen and carbon.

The bark of oak, and other aſtringent vegetables, but particularly the gall nut, contain a ſubſtance which has been called the aſtringent principle; it has lately been diſcovered to be a peculiar acid, and is called the gallic acid. This acid has a ſtronger attraction for metallic oxyds, than any other acid; it precipitates iron from its ſolution in the form of a fine dark blue, or black powder; which, ſuſpended in water by means of gum, makes the common writing ink.

The gallic radical is not known, but it may be changed into the oxalic acid by means of the nitric, and is ſuppoſed to conſiſt of carbon and hydrogen.

If amber be diſtilled in cloſe veſſels, there ſublimes from it a peculiar acid called the ſuccinic acid. The compounds formed by this acid with different ſubſtances, are called ſuccinats.

Borax is compoſed of ſoda, and a peculiar acid called the boracic acid; this acid may be procured from borax by means of the ſulphuric, and has been called ſedative ſalt. The combinations of this acid with different ſubſtances, are called borats, but are little known, excepting the borat of ſoda, or common borax, which is very uſeful in ſome of the arts. The boracic radical is not known.

Fluor-ſpar is compoſed of lime, or calcareous earth, combined with a peculiar acid called the fluoric acid. This acid may be procured from the ſpar by means of the ſulphuric. The fluoric acid ſhould be kept in leaden veſſels, as it diſſolves glaſs very readily. This property affords an eaſy method of etching on glaſs. The name of fluat is given to the combinations formed by this acid with different ſubſtances; we are however little acquainted with any of theſe combinations excepting fluat of lime.

If dried blood be mixed with potaſh, and expoſed to a red heat for ſome time, a peculiar acid unites with the potaſh, called the pruſſic acid, and the combination which was formerly known by the name of phlogiſticated alkali, is called pruſſiat of potaſh.

The pruſſic acid precipitates the metallic oxyds from their combinations with other acids. Iron is precipitated by this acid in the form of a beautiful blue powder, commonly called pruſſian blue, but in the new Nomenclature, pruſſiat of iron. The pruſſiat of potaſh is a very delicate teſt of the preſence of iron.

The radical of the pruſſic acid is ſuppoſed to be compoſed of carbon and azote, with a ſmall quantity of hydrogen.

There are ſeveral other acids, but they only differ from thoſe we have conſidered, in the proportions of the component parts of their radicals. They are generally convertible one into the other, and their compounds are of little conſequence.

LECTURE XXI.

THOUGH there ſeems to be an almoſt infinite variety of earthy ſubſtances ſcattered on the ſurface of this globe; yet when this ſubject is examined with a chemical eye, we ſhall find, not without ſurprize, that all the earths and ſtones which we tread under our feet, and which compoſe the largeſt rocks; and that the vaſt variety of ſpecimens which adorn the cabinets of the curious, are compoſed of a very few elementary earths, ſcarcely exceeding five in number.

Of theſe five elementary earths, two are in ſome meaſure more dry, hard, inſipid, and inſoluble; while the other three poſſeſs ſaline properties, which render them akin to the ſubſtances denominated alkalies. Theſe three, which have in conſequence

been

been termed ſalino-earthy, and alkaline earths, are *barytes*, *magneſia*, and *lime*. The other two are, *ſilex* and *alumin*. Some other earths have been lately diſcovered, but they are found in very ſmall quantity, ſuch as the adamantine earth, and jargon.

All the earthy and ſtony ſubſtances we meet with are compoſed of ſome or all of the five earths juſt enumerated. Their general character is dryneſs, indeſtructibility, and infuſibility, beſides which, each has ſpecific characters.

Silex is rough to the touch, cuts glaſs, and ſcratches or wears away metals ; its weight is about 2, 5 that of an equal bulk of water. It is infuſible, incombuſtible, and inſoluble in moſt acids; but ſoluble in alkalies with the aſſiſtance of heat, forming glaſs. It is found in great abundance in ſand, quartz, flint, agate, grit, and almoſt all ſtones that ſtrike fire with ſteel.

Alumin, or argil, is ſoft to the touch, adheres to the tongue, and hardens in fire, contracting in its dimenſions, and when expoſed to an extreme heat, it becomes ſo hard as to ſtrike fire with ſteel.

When mixed with water and ſilex in proper proportions, it forms porcelain ; it conſtitutes the greateſt part of clays, ſchiſts, ſteatites, &c. and forms the baſis of all kinds of earthenware.

With the ſulphuric acid it forms ſulphat of alumin, a ſalt much uſed in different arts under the name of alum, of which there are two different kinds, the common and roch alum, which do not however differ in their chemical properties. This ſalt has a ſtrong ſtyptic taſte, and is evidently ſuperſaturated with the ſulphuric acid. It diſſolves in fifteen times its weight of cold water. The combinations of this earth with the other mineral acids are not intereſting.

Barytes, or heavy earth, is exceedingly white and pure, and is ſoluble in about 900 times its weight of cold water, to which it communicates a taſte and properties ſimilar to lime-water. Its ſpecific gravity is to that of water as four to one. It is precipitated from its combinations with the different acids by the pruſſiat of potaſh, like metals ; from theſe circumſtances, there is reaſon to ſuſpect it to be a metallic oxyd, but chemiſts have never yet procured it in a metallic or deoxydated form.

The moſt common form in which we meet with this earth, is in combination with the ſulphuric acid, forming ſulphat of barytes, or heavy ſpar, the ſpecific gravity of which is to that of water as 4,5 to 1. It generally accompanies metallic veins.—This ſubſtance is nearly inſoluble in water.

With carbonic acid this earth forms carbonat of barytes, which does not appear to exiſt in great quantity in nature. One hundred parts of carbonat of barytes contain twenty-eight of water, ſeven of carbonic acid, and ſixty-five of barytes.

Barytes forms with the nitric acid, nitrat of barytes, a ſalt which has never been found native, and is little known.

This earth forms with the muriatic acid, the muriat of barytes, a ſalt ſeldom if ever found formed by nature. This ſalt is one of the beſt teſts of the preſence of the ſulphuric acid.

Magneſia is never found naturally pure, but generally combined with the ſulphuric acid. To procure it pure, it muſt be precipitated from this combination by means of an alkali.

This earth is extremely white, light, and ſpungy;

gy; with acids it forms ſalts, which are extremely ſoluble, and ſince it has a weaker affinity for acids than lime, it is eaſily ſeparated from them by that ſubſtance.

With the ſulphuric acid it forms ſulphat of magneſia, better known by the name of Epſom ſalt. This ſalt is found in great plenty in the bitter liquor that remains after the cryſtallization of common ſalt, made from ſea-water, and the greateſt part of the magneſia in uſe, is procured by precipitating the earth from this ſalt. One hundred parts of the ſulphat of magneſia contain twenty-four of acid, nineteen of earth, and fifty-ſeven of water.

The nitrat of magneſia is extremely diliqueſcent. This ſalt is little known.

The muriat of magneſia is likewiſe very diliqueſcent, and remarkably bitter. It is contained in ſea water, and in the water of ſome ſaline ſprings.

Carbonat of magneſia, or mild magneſia, is ſeldom found formed by nature, but obtained by precipitating the magneſia from the ſulphat of magneſia by a carbonated alkali. One hundred parts of this ſalt generally contain thirty of carbonic acid, forty-eight of magneſia, and twenty-two of water. The carbonic acid may be driven off by a violent heat, and the earth which remains is pure or calcined magneſia.

Lime is very ſeldom found pure, but generally combined, and chiefly with the carbonic acid; it may however be procured pure by expelling the carbonic acid by means of heat. It is ſoluble in 680 times its weight of water, forming lime water, which has an alkaline taſte, and peculiar properties. Pure lime attracts water with great avidity, which becomes fixed or ſolid in it, and giving out its latent heat, cauſes the maſs to become extremely hot.

The combination of lime with the carbonic acid is by much the moſt common, and comprehends all thoſe ſtones or rocks, which are known by the names of chalk or limeſtone, or under the general name of calcareous earth.

The characters of carbonats of lime are the following—Firſt, they efferveſce with acids. Second, they are convertible into lime by calcination. There are many reaſons to believe, that nearly all the calcareous earth which we meet with on the ſurface of the globe, in the form of limeſtone, chalk, marble,

&c.

&c. derives its origin from the deſtruction of the ſhells of marine animals. Lime, mixed with ſand, and tempered with water, forms mortar. This important cement has been much improved by the reſearches of Dr. Higgins.

Lime, combined with the ſulphuric acid, forms ſulphat of lime, gypſum, or plaſter of Paris. One hundred parts of this ſalt contain thirty of ſulphuric acid, thirty-two of lime, and thirty-eight of water. This ſalt is generally formed by the decompoſition of pyrites, which happens to be incumbent on beds of calcareous earth. It is ſoluble in about one hundred times its weight of cold water. It is uſed for making caſts, and ornaments for buildings.

The nitric and muriatic acids form with lime diliqueſcent ſalts, which are little known.

The fluoric acid combines with lime, and forms fluat of lime, or Derbyſhire ſpar. Lime is likewiſe found combined with the phoſphoric acid, and this conſtitutes the earthy part of the bones of animals.

LECTURE XXII.

METALS are ſubſtances diſtinguiſhed by their weight and luſtre: they are fuſible, cryſtalliſable, and combuſtible; they decompoſe water, and ſeveral acids, and are converted into metallic oxyds. They have by chemiſts been generally divided into three claſſes, ſemimetals, imperfect metals, and perfect metals. This diviſion, as is properly obſerved by Fourcroy, has evidently derived its origin from the erroneous ideas of alchemy. He divides metals into five genera: in the firſt are compriſed brittle and acidifiable metals: this genus contains three ſpecies, arſenic, tungſten, and molybdena. The ſecond genus contains thoſe which are brittle, and ſimply capable of oxydation, of which there are five ſpecies, cobalt, biſmuth, nickel, mangeneſe, and antimony: the third genus includes the ſemi-ductile and oxydable metals, of which there are two, zinc and mercury. The fourth genus contains ſuch metals as are perfectly ductile, but at the ſame time eaſily oxydable: ſuch as tin, lead, iron, and copper. The fifth and laſt genus comprehends thoſe that poſſeſs perfect ductility, but which are not oxydable without great difficulty. This genus comprehends three ſpecies, ſilver, gold, and platina.

Though there are various circumſtances under which metals may be united with oxygen, they may in general be reduced to three. Firſt, the contact of air, aſſiſted by caloric. Second, by decompoſing water. Third, by decompoſing acids.

Different metals require different quantities of oxygen to convert them into oxyds; and each metal, ſeparately conſidered, abſorbs different proportions of oxygen, and ſtops at various points of oxydation, according to the degree of temperature to which it is raiſed.

Metals differ in their attraction for oxygen. Some have ſo weak an affinity for that ſubſtance, that if their oxyds be ſimply expoſed to the light, the oxygen ſeparates from them; ſuch are gold and ſilver. Others, as mercury, require for its ſeparation

tion a conſiderable degree of caloric and light.— Others have ſo ſtrong an attraction for oxygen, that it cannot be ſeparated from them merely by the action of caloric and light; nothing but the addition of a combuſtible ſubſtance can effect this decompoſition.

Metals cannot be diſſolved in acids, unleſs they be previouſly oxydated, but when the acid is diluted with water, the metal decompoſes the water, becomes oxydated, and is then diſſolved by the acid. As an exception to this however, it may be obſerved, that metals can be diſſolved in the nitric acid without the addition of water; for they decompoſe a part of the acid, attract its oxygen, and are then diſſolved by the remainder.

Few of the metals, except gold and platina, are found pure, but generally in the form of oxyds, or ores. Theſe metallic ores, excepting thoſe of iron, are never found in regular ſtrata like the earths, but in cavities, or rents, which run among the earthy ſtrata in all directions. From this, and other circumſtances, it ſeems probable that metals are contained in large quantities in the interior parts of the earth, and that, by ſubterraneous fires, they are forced into rents near the ſurface.

To convert metallic ores into metals, they are firſt roaſted, to drive off the ſulphur and arſenic, then fuſed along with ſubſtances capable of attracting their oxygen. The unmetallic parts are vitrified, and float on the ſurface, while the metal falls to the bottom of the furnace.

We ſhall now conſider each of the metallic ſubſtances in the order in which they were enumerated.

Arſenic is a dark coloured metallic ſubſtance reſembling antimony, but its oxyd is white. This oxyd, which is improperly called arſenic, is ſoluble in about eighty times its weight of cold water, or fifteen times its weight of boiling water. Oxygenated muriatic acid digeſted upon this ſubſtance, converts it into arſenic acid, by imparting its ſuperabundant oxygen. The oxyd of arſenic is uſed in a variety of arts, but is a moſt deadly poiſon. The beſt antidote is the ſulphuret of potaſh, which decompoſes the oxyd, and renders it in a great meaſure harmleſs. If any ſubſtance containing arſenic be mixed with oil, or powdered charcoal, and thrown upon a red hot iron, a ſmell like that of garlick will be perceived.

Tungſten is of a browniſh or black colour, radiated and ſhining; it is granulated, friable, and almoſt infuſible; ſcarcely ſoluble in the acids, but converted into an acid by the action of air and caloric.

Molybdena reſembles plumbago in appearance; but in its texture is ſcaly, and not eaſily pulveriſed. By heat it is converted into a white oxyd.

Cobalt is of a grey or ſteel colour, cloſe grained, difficult to fuſe, and not eaſily oxydated. It is generally however found in the ſtate of an oxyd, mineralized by ſulphur and arſenic. The oxyd of cobalt when fuſed, forms a beautiful blue glaſs called ſmalt, which is uſed in ſeveral manufactures.

Cobalt is ſoluble in the acids, particularly in the ſtate of an oxyd; but does not form any intereſting combinations, excepting the ſolution of it in the nitro-muriatic acid, which forms a curious ſympathetic ink.

Biſmuth is compoſed of cubes, formed by the application of plates to each other; it has a rediſh tinge, particularly when expoſed to the air; it is nearly ten times heavier than water, is not malleable, but eaſily reduced to powder. It is ſoluble in the acids, from which it is precipitated by water alone, in the form of a white oxyd, which is much uſed as a coſmetic.

Nickel has a rediſh caſt, great hardneſs, is magnetic, and very infuſible. It is ſoluble in the acids. It is often found mineralized by copper, forming cupfer-nickel; it has not yet been applied to uſe.

Manganeſe is of a dull white colour when in its metallic ſtate, but grows black when expoſed to the air. Its attraction for oxygen is ſo great, that it is always found in the form of an oxyd, which is black, hard, and ponderous; it contains nearly half its weight of oxygen, which may be procured from it in the form of gas merely by heat. There is another oxyd of manganeſe, called black woad, which inflames ſpontaneouſly when mixed with linſeed oil.

Antimony is of a whitiſh ſilvery colour, and ſcaly texture; it melts ſoon after ignition, and ſoon oxydates. It detonates with nitre, and forms oxydated antimoniated potaſh. It is generally found mineralized by ſulphur, in the form of ſulphuret of antimony, or crude antimony, which is convertible by heat into a dark coloured glaſs, commonly called crocus metallorum.

This metal is often uſed in medicine. The preparations at preſent moſt uſed are antimonial wine, and antimonium tartariſatum, or emetic tartar. James's fever powder is likewiſe a preparation of antimony.

LECTURE XXIII.

ZINC is a metal of a bluiſh caſt, brighter than lead, and ſo far malleable as not to be broken by a hammer, though it cannot be much extended. It melts long before ignition, and when heated a little above its melting point, particularly if agitated, it burns with a dazzling white flame, and oxydates with great rapidity. The oxyd thus formed is volatile, and condenſes into a flocculent maſs, which has been called flowers of zinc, or philoſophical wool.

This metal is very volatile; it is generally found mineraliſed by ſulphur in the ore called blend: there is likewiſe another one of zinc, called calamine. It is generally found mixed with more or leſs lead, and ſometimes in ſuch quantity in the Eaſt Indies, that it is fuſed in that ſtate, and forms the metallic compound known by the name of Toutenag. Diluted ſulphuric acid diſſolves zinc rapidly, and a great quantity of very pure hydrogen gas is driven off, which ariſes from the decompoſition of the water. The ſulphat of zinc may be procured in white cryſtals. The muriatic and nitric acids diſſolve zinc, but the compounds formed by them with this metal are very little known.

Zinc, precipitated from its ſolution in the ſulphuric acid, in the ſtate of an oxyd, forms a pigment in every reſpect ſuperior to white lead.

Mercury differs from the other metals in preſerving its fluidity in the common temperature of the atmoſphere, but if cooled down to 39° below 0, it becomes ſolid, hard, and malleable. This metal is fourteen times heavier than water; it evaporates in low degrees of heat, and boils at about 600°.

When expoſed to the air, and heated ſomewhat ſhort of its boiling point, its ſurface becomes ſlowly oxydated, forming the red oxyd of mercury; from which the oxygen may be expelled in a very pure ſtate by expoſing it to a red heat.

The ſulphuric acid when hot, is decompoſed by mercury, while the metal is converted into a yellow oxyd, which was formerly called turbith mineral.

Mercury diſſolves very readily in the nitric acid, oxydating itſelf by decompoſing part of the acid, and the oxyd is diſſolved in the remainder.

The muriatic acid unites with the mercury diſſolved in the nitric acid, and if the oxygenated muriatic acid be employed, corroſive ſublimate is formed, or the oxygenated muriat of mercury; but if the common muriatic acid be uſed, then the ſubſtance formed is muriat of mercury, or calomel.

Corroſive ſublimate is ſoluble in nine times its weight of water, from which it may be precipitated by barytes, magneſia, or lime.

Mercury combines with ſulphur by trituration, forming a black powder, which has been called Ethiops, mineral. A more intimate combination is formed by heat, which is called cinnabar, which ſubſtance powdered, forms vermillion.

Mercury is uſually found mineralized by ſulphur, in the form of cinnabar; very ſeldom pure. It readily combines with moſt metals, forming what is called an amalgam. Looking glaſſes are covered on the back with an amalgam of mercury and tin.

Mercury is uſed in various arts, and in medicine.

Tin is a metal of a ſlight yellow caſt, harder than lead, but very malleable, and capable of being extended into thin plates called tin foil. It is the lighteſt known metal, extremely fuſible, and when melted, it oxydates very rapidly. The oxyd of tin is very infuſible, and is uſed to make white opaque enamels. Thin ſheets of iron, coated with tin, are uſed to make a variety of utenſils.

Tin readily unites with different metals, and an amalgam compoſed of two parts of mercury, one of zinc, and one of tin, renders the action of electrical machines very powerful.

Concentrated ſulphuric acid, aſſiſted by heat, diſſolves tin, but part of the acid is decompoſed. If the acid be diluted with water, the oxyd of tin is precipitated. Nitric acid attacks tin violently, part of it is decompoſed and oxydates the tin, and the remainder diſſolves the oxyd as it is formed.

The muriatic acid alſo diſſolves tin, but the nitro-muriatic acid diſſolves it much more readily, forming a gelatinous kind of liquor, the nitro-muriat of tin, which is uſed by dyers to brighten the colour of ſome red tinctures. Tin detonates with nitre; and if tin foil be wetted with a ſolution of nitrat of copper, heat and flame will be produced.

Tin is the principal ingredient in the compoſition of pewter, the other ingredients are lead, zinc, biſmuth, and copper. Tin is alſo uſed for coating copper veſſels: it is ſometimes found native, but generally mineralized by ſulphur and arſenic.

Lead has no great tenacity, but very conſiderable ſpecific gravity; it melts long before ignition, and begins to oxydate. In its firſt degree of oxydation it is yellow, and has been called maſsicot; by imbibing more oxygen it becomes red, and is then called minium, or red lead; more properly the red oxyd of lead. If a great heat be quickly applied, this oxyd is converted into litharge, and by a ſtill greater heat into glaſs.

Lead unites with moſt metals, but not with iron. Two parts of lead, and one of tin, form ſoft ſolder, which melts with leſs heat than either of the metals; but a compoſition of biſmuth, lead, and tin, in proper proportions, makes a compound ſo fuſible, that it melts in boiling water.

Sulphuric acid will not act upon lead unleſs boiling; it is then decompoſed and oxydates the metal. Nitric acid readily converts it into an oxyd, which is diſſolved by the diluted nitric acid, forming nitrat of lead.

The affinity of the muriatic acid for lead is ſo ſtrong, that this metal decompoſes all the muriats; and on this principle, ſome manufactures for the ſeparation of ſoda from common ſalt have been eſtabliſhed. The muriat of lead formed in this operation is of a beautiful yellow colour, and uſed as a pigment. The acetous acid oxydates lead, and forms white lead. All the oxyds of lead are ſoluble in the acetous acid, and the ſolution evaporated forms acetite, or ſugar of lead. If this acetite of lead be diſſolved in water, and the lead precipitated by zinc, it aſſumes a beautiful ramified appearance.

Lead is ſometimes improperly uſed to ſweeten ſome wines, but may be detected by Hahnemann's teſt.

The uſes of lead are very numerous; perſons who work much among lead, are ſubject to a complaint called *colica pictonum*, which may be remedied by ſulphuret of potaſh. Lead is ſeldom found native, but generally mineralized by ſulphur and arſenic. It is ſometimes, though ſeldom, found combined with phoſporic acid.

Iron is the hardeſt and moſt elaſtic of all the metals, and excepting platina, the moſt difficult to be fuſed. Next to gold, it has the greateſt tenacity of parts. It is about ſeven times heavier than water. This metal is more uſeful than any other; it has a very ſtrong attraction for oxygen, which converts its ſurface into an oxyd, or ruſt. Iron has the peculiar property of welding in a white heat.

If iron be deprived of its oxygen as much as poſſible by placing it in contact with red hot charcoal, it becomes much more hard and pure, and is called ſteel.

Sulphuric acid diluted diſſolves iron, and during the ſolution a great quantity of hydrogen gas flies off. The ſulphat of iron thus formed is of a green colour; but is never made for uſe by art, being extracted from pyrites, or ſulphuret of iron.

Nitric acid acts very eagerly on iron, and is decompoſed, and the iron is thrown down in the form of a red oxyd.

The muriatic acid diſſolves iron, and forms a ſalt, which may be procured in cryſtals.

Iron is very ſeldom found pure in nature, but generally combined with ſome other ſubſtance; moſt commonly with oxygen. It is often combined with ſulphur, forming pyrites, the figure of which is ſometimes very beautiful. It is ſometimes combined with carbon, and then is called plumbago, or black lead.

Iron is never found in veins, like the other metals, but ſtratified like the earths: and there are ſtrong reaſons for ſuſpecting that the greateſt part, if not all the iron on this globe, has been of animal or vegetable origin.

LECTURE XXIV.

COPPER is of a dull red colour, and a fine granulated texture when broken; it poſſeſſes conſiderable ductibility, and may be drawn into fine wire, or beaten into thin leaves; it is rather more than eight times heavier than water.

Almoſt all the acids diſſolve this metal, but what is remarkable, they diſſolve more of it by ſtanding in the cold, than by boiling.

Sulphuric acid, when concentrated and hot, diſſolves copper, forming ſulphat of copper, or blue vitriol, which may be procured in beautiful blue cryſtals. One hundred parts of this ſalt contain thirty of acid, forty-three of water, and twenty-ſeven of copper.

The nitric acid attacks copper very rapidly, and is decompoſed. The nitrat of copper is a green diliqueſcent ſalt, which has the curious property of exploding when moiſtened and rolled up in tin foil, as has been before noticed. The muriatic acid when concentrated, diſſolves copper, but the muriat of copper is very little known.

The vegetable acids diſſolve copper very eaſily, on which account the uſe of this metal for culinary purpoſes is very improper. The ſolution of copper in the acetous acid, forms acetite of copper, which may be procured in cryſtals of a beautiful green colour, and which is commonly called verdigris.

Copper readily unites with melted tin, at a temperature much lower than what is neceſſary to melt the copper; by which means copper veſſels are eaſily covered with a coating of tin.

A mixture of copper and tin forms bronze; two parts of copper and one of zinc form braſs, and with different proportions, prince's metal. Copper is ſometimes found native, but generally combined with ſulphur and oxygen, in ores of a red, green, or blue colour.

Silver is white, very ductile, and about eleven times heavier than water. If ſilver, finely divided, be immerſed in concentrated and boiling ſulphuric acid, the acid is decompoſed, and a large quantity of ſulphurous gas flies off; and the ſilver is reduced to a white oxyd.

The nitric acid diſſolves ſilver very rapidly, and when fully ſaturated, this ſolution depoſits cryſtals of nitrat of ſilver. The nitrat of ſilver is an excellent teſt for diſcovering the preſence of the muriatic acid.

A fulminating property may be imparted to the oxyd of ſilver, precipitated from this ſolution, which is much more extraordinary and terrible than any other ſubſtance with which we are acquainted. The ſilver is precipitated from the ſolution by lime-water, and afterwards waſhed with ammoniac.

Gold is the moſt perfect and indeſtructible of metals; it appears yellow by reflected light, but green by tranſmitted light. It is ſo tenacious, and at the ſame time ductile, that a grain of it may be beaten out ſo as to cover fifty-ſix ſquare inches, but when it is uſed to cover ſilver wire, it is ſpread over a ſurface 12 times as great. Pure gold is nineteen times heavier than water; it melts in a low degree of white heat; it readily unites with the other metals, and particularly with mercury; and on this depends the practice of gilding metals.

Neither the ſulphuric, muriatic, or nitric acids, have any effect on Gold, but the nitro-muriatic acid diſſolves it very eaſily; and if it be precipitated from the ſolution by means of ammoniac, the precipitate explodes when heated, with very great violence.

Gold is generally found pure, mixed with earth, or diffuſed in fine grains through ſtones.

Platina is generally found in the gold mines in ſmall particles, and it is the heavieſt body with which we are acquainted, being at leaſt twenty two times heavier than water. It is harder than gold or ſilver, and has the property of welding with iron.

This metal is inſoluble in any of the acids, excepting the nitro muriatic and oxygenated muriatic acids; it unites with the other metals, and with copper forms a compound, ſuſceptible of a fine poliſh, and not liable to tarniſh.

From the earlieſt ages of chemiſtry, it has been thought poſſible to convert metals into each other; and this tranſmutation, though hitherto undiſcovered by the alchymiſts, does not appear abſolutely impoſſible: modern chemiſtry having ſhown the analogy between metallic oxyds and acids, may perhaps in time lead to the power of tranſmuting their baſes.

Dr. Darwin's theory of the formation of the earth, is very bold and ingenious; he ſuppoſes the ſun to conſiſt of ſimilar materials to what compoſe the interior and primary matter of this globe; that during a ſolar volcano, the earth, along with the other planets; might be projected from the ſun; that the rotation of the earth might be occaſioned by its adheſion to one ſide of the cavity from which it was projected; and that from its rotation, as it was then in a liquid ſtate, it would acquire its ſpheroidal form.—The heavieſt ſubſtances, viz. the metals, would fall towards the center, and over theſe would be depoſited the earths which compoſe granite and baſaltic rocks; as it cooled, theſe earths would form a nucleus; and the attending and ſurrounding vapours, being condenſed, would form the ocean, which ſurrounds the whole globe.

On the nucleus of granite covered by the ocean, would be formed calcareous beds of limeſtone, marble, and chalk, from the exuviæ of marine animals; theſe would become ſtratified, from their having been formed at very different or diſtant periods of time. The whole terraqueous globe was problably then rent by central fires; iſlands and continents would be raiſed, conſiſting of granite or lava in ſome parts, and limeſtone in others; in conſequence of this, great vallies would be ſunk, into which the ocean would retire.

On ſome parts of theſe iſlands and continents of granite and limeſtone, would be gradually produced extenſive moraſſes, from the recrements of vegetables and land animals; and from theſe would be produced, clay, coal, ſulphur, and iron, with the baſes of a variety of acids, all of which would be ſtratified.

In the elevation of the mountains by ſubterraneous fires, very numerous and deep fiſſures would neceſſarily be produced. Into theſe fiſſures, many of the metals would be raiſed, either from their being forced into them in a liquid ſtate, or which is more probable, from their particles being evaporated, condenſed, cryſtallized, and mineralized, in thoſe cavities; hence we ſhould expect to find the moſt volatile metals in the greateſt quantities, and *vice verſa*, which is conſonant to experience.

LECTURE XXV.

THE chemical ſubſtances which have been hitherto examined, have no life or peculiar organization, excepting what reſults from the attraction of their particles. We now proceed to the chemical conſideration of thoſe ſubſtances, which poſſeſs ſuch an organization and irritability, as enable them to fulfil the two great ends deſtined by nature;—the continuation of their own exiſtence, and the reproduction of their ſpecies.

Though it may at firſt ſight appear very eaſy to diſtinguiſh the three kingdoms of nature from each other; yet there is ſuch a gradation, ſuch an imperceptible tranſition of one kingdom into another, that it is difficult to give a characteriſtic definition of one which embraces all the individuals of it, and at the ſame time excludes all thoſe of the other kingdoms. Indeed, on inquiry we ſhall find, that there is no natural diſtinction of this kind, and that there is not a function common to vegetables and minerals, which ſome of the animal tribe do not enjoy, and *vice verſa.*

The ſubſtances conſtituting the texture of vegetables differ from mineral bodies, in being of a more complex order of compoſition; and though vegetables are extremely ſuſceptible of decompoſition by analyſis, not one can be ſynthetically produced.

Though the analyſis of vegetables ſhews that they are compoſed of four or five ſimple ſubſtances, viz. caloric, light, water, air, and carbon, yet nothing but the texture and organs of living vegetables, can from theſe ſubſtances form the matters from which they are extracted.

Though vegetable bodies are compoſed of theſe few ſimple principles, yet we find a great variety of ſubſtances produced by their combination; theſe may be reduced to a certain number of principal heads, which, with Fourcroy, we ſhall call the immediate materials of plants, becauſe they are obtained from them by ſimple proceſſes, almoſt wholly mechanical; and by a kind of direct analyſis, which does not alter the nature of the products.

Among theſe immediate materials of vegetable bodies, are the following ſubſtances, either fluid or ſolid. Extractive matter; mucus, or mucilage; ſugar; eſſential ſalts; fixed oil; volatile oil; aroma; camphor, reſin; balſam; gum-reſin; fecula; gluten; colouring matter; elaſtic gum; and wooddy fibre. Of theſe immediate materials, which are formed of ſome or all of the ſimple ſubſtances before mentioned, all known vegetables are compoſed. The properties of each of theſe materials are particularly pointed out in the lecture.

Since theſe immediate materials are all compoſed of, and capable of being ſeparated by analyſis, chiefly into carbonic and water; it may be proper to inquire how vegetables procure the principles which form theſe materials.

Water is evidently the ſource whence vegetables derive the hydrogen; this fluid is decompoſed in their glands, aſſiſted by ſolar light, and becomes fixed in them in the ſtate of oil, extract, mucilage, &c. The greateſt part of the vegetable however conſiſts of carbon, which they procure from the decompoſition of the carbonic acid floating in the atmoſphere, or diſſolved in the water, which is abſorbed by them; when theſe vegetables decay, their mould affords carbon to future vegetables, which nouriſhes them luxuriantly. This mould, or carbon, is however gradually exhauſted by vegetation when the crop is carried off, and then the farmer is obliged to ſupply freſh quantities of carbon, which is generally done in the form of dung; the rain water which falls on the ground thus manured, becomes ſaturated with carbon, and then contains all the principles of vegetation.

LECTURE XXVI.

ANIMAL ſubſtances differ from vegetable, principally in the following circumſtances. Firſt, they afford a conſiderable portion of ammoniac, and very fœtid products by the action of fire. Second, they putrefy more eaſily and ſpeedily, giving out a much worſe ſmell. Third, they yield when acted on by the nitric acid, a much greater quantity of azotic gas, and laſtly, they contribute ſingularly to the formation of nitric acid.

Theſe differences ſeem to depend on animal bodies being poſſeſſed of one ſubſtance in much greater abundance than vegetables, viz. azote. Beſides theſe circumſtances, in which animal ſubſtances differ from vegetable, the former generally contain a quantity of phoſphoric acid and calcareous earth.

Azote, which is ſo abundant in animal ſubſtances, is undoubtedly the cauſe of their concreſcibility and plaſticity. If we ſhould deprive animal ſubſtances of their azote, they would be converted into ſubſtances reſembling vegetables, and if we could introduce azote into vegetable ſubſtances, we ſhould animalize them.

All matters which form the bodies of animals, and which may be extracted from them without altering their nature, may be conſidered as ſo many immediate principles, as was done with reſpect to vegetables.

The principal animal fluids are, Firſt, the blood, which conſiſts of three immediate materials, or principles, the ſerum, the craſſamentum, or coagulable part, and the colouring part, or red globules, as they are called. Second, milk, which is the leaſt animalized of all the fluids, and conſiſts likewiſe of three immediate materials, ſerum, or whey, butter, and cheeſe. Third, the bile, which is a ſaponaceous fluid, conſiſting chiefly of an animal oil, combined with ſoda. Fat is nothing but animal oil in a coagulated ſtate.

The ſubſtances which compſe the ſolid parts of animals may likewiſe be divided into three immediate materials, or principal genera; Firſt, Albumen. Second, Gelatin. Third, Fibrin, or Fibrous matter. Theſe three ſubſtances in a ſtate of concretion and combination, form all the ſolids of animals, and are ſeparable from each other by an eaſy analyſis. Theſe different immediate principles are particularly examined in the lecture.

By whatever means we deprive animal ſubſtances of their azote, we reduce them to ſubſtances reſembling vegetables; the muſcular fibre excluded from the contact of the air, but particularly if in contact with water, parts with its azote, and is converted into a ſubſtance reſembling ſpermaceti, which in its analyſis, agrees with the common expreſſed oils of vegetables.

When vegetables and animals are deprived of life, movements are excited in them which deſtroy their texture, and alter their compoſition. Theſe movements conſtitute the different kinds of fermentation.

When the ſaccharine principle is predominant in vegetables, the product of fermentation is a ſpirituous, or vinous liquor; when mucilage is predominant,

dominant, the product is an acid, and if the gluten ſhould prove moſt abundant, the fermentation will be of the putrefactive kind. Hence it is evident that vegetable ſubſtances may ſucceſſively experience all the different kinds of fermentation.

When vegetable ſubſtances, particularly ſaccharine matters, are mixed in proper quantity with water, and expoſed to a gentle heat, the water becomes decompoſed ; its oxygen combines with the carbon of the vegetable, forming carbonic acid, which is diſengaged in large quantity during fermentation ; at the ſame time, the hydrogen of the water, uniting with the mucilage, forms alkohol, which being mixed with water, and part of the carbon of the ſaccharine matter, together with extractive and colouring matter, is called wine. The alkohol may be ſeparated from theſe matters by diſtillation with a gentle heat. Pure alkohol appears to be hydrogen in a liquid ſtate, combined with a ſmall quantity of carbon, which moſt probably cauſes its fluidity ; for we find that the more we deprive it of its carbon, the nearer it approaches to the ſtate of hydrogen gas. Ether ſeems to be hydrogen, combined with much leſs carbon. It is convertible into gas with a gentle heat, which very much reſembles hydrogen gas in its properties.

The acid fermentation is the next natural movement, which contributes to reduce vegetable compounds to more ſimple ſtates of compoſition. After vegetables have paſſed through this ſtate, their decompoſition continuing under favourable circumſtances, leads to the decompoſition of the laſt principle, the gluten, which terminates in volatalizing moſt of their principles in the form of gas; after this, nothing remains but a brown or black reſiduum, called mould, compoſed of carbon, ſome ſalts, a little oil, and extractive matter.

When animal ſubſtances, deprived of life, are expoſed to the air, their component parts ſoon become altered by more ſimple attractions between their principles, which have a tendency to unite two and two together. In the union of hydrogen and azote, we perceive the formation of ammoniac, the combination of carbon with oxygen, explains the evolution of carbonic acid. Nitric acid ariſes from the union of oxygen and azote. A quantity of hydrogen is extricated in the form of gas, carrying off with it ſulphur and phoſphorus, which cauſes the diſagreeable ſmell that attends animal putrefaction; nothing now remains but a portion of carbon, mixed with phoſphat of ſoda and phoſphat of lime.

Hence we ſee, that by the proceſſes of fermentation and putrefaction, complex bodies are converted into ſubſtances leſs compound; and that nature reſtores, in the new combinations that are formed, the principles ſhe had borrowed from the atmoſphere for the formation of animals and vegetables; and thus ſhe accompliſhes the perpetual circle of compoſitions and decompoſitions, which demonſtrates her fecundity, while it announces equal grandeur and ſimplicity in her operations.

LECTURE XXVII.

FROM the analyſis of vegetables ſubſtances it appears, that they are compoſed chiefly of three principles, carbon, hydrogen, and oxygen; the whole of the woody fibre conſiſts of carbon, the other parts of the vegetable conſiſt of modifications of theſe three principles, ſo that carbon is the principle which is contained by vegetables in the greateſt quantity.

Since vegetables as well as animals will be diſeaſed, if they receive either too little or too much nouriſhment, it is evident that the great buſineſs of agriculture muſt be,

1. To ſupply plants with proper nouriſhment.

2. To ſupply that nouriſhment in proper quantity.

The firſt is accompliſhed by the application of manures; the latter depends upon the ſimple elementary earths in which plants grow, being of ſuch conſiſtency or in ſuch proportion, as to tranſmit nouriſhment to plants in proper quantity.

From the decompoſition of water, plants gain their hydrogen, and in the caſe where they are not ſupplied with carbon directly in the form of manure, but only abſorb water impregnated with carbonic acid, it is evident that they muſt decompoſe that acid, and apply the carbon to the formation of the woody fibre. As much of the oxygen of the water and carbonic acid as is neceſſary to form the vegetable juices is retained, while the remainder is perſpired by the plant in the form of gas, which purifies the atmoſphere.

There is no doubt then that plants do obtain carbon by the decompoſition of the carbonic acid which is diſſolved in water; yet this fluid ſeldom contains a ſufficient quantity of that gas to make vegetables grow vigorouſly and luxuriantly. In grounds however, where vegetables are not carried off, but ſuffered to decay, their relicks afford a ſufficient quantity of carbon for the nouriſhment of the future vegetable; but if the crops be taken off, this carbon will in a few years be exhauſted; and if the ſame crop is to be continued, a freſh quantity of carbon muſt be ſupplied by the farmer. Carbon not only forms the reſiduum of all vegetables which have decayed, or undergone a ſmothered combuſtion, but alſo of all putrid vegetable and animal bodies; hence it is found in all vegetable and animal bodies that have undergone putrefaction, and is the true baſis of their nutritive powers, as manures. Carbon however cannot produce its beneficial effects unleſs it be ſoluble in water, for in no other ſtate can it be abſorbed by the plant. The proceſs of both animal and vegetable putrefaction is accompanied by that of oxygenation, forming carbonic acid, which is eagerly diſſolved in water and abſorbed by plants. But all vegetables after death, even before putrefaction, unite with a quantity of oxygen, though not ſufficient to convert them into carbonic acid; and in this ſtate they form excellent manures, for though they are then in a great meaſure inſoluble, yet when ſpread upon the ſurface of the ground, they are by the action of air and water, converted into carbonic acid.

To this proceſs of partial oxygenation, the continuance of vegetable matter on the ſurface of the earth is to be chiefly aſcribed.

Having ſhown what is the proper food of plants, and that if they be ſupplied with water and carbon, and expoſed to the influence of light, which aſſiſts in the decompoſition of the water and carbonic acid, they will grow and live, I ſhall next take a ſhort view of the nature of ſoils, or the mixture of the ſimple earths moſt proper for tranſmitting theſe nutritive principles to vegetables.

The earths in which vegetables grow, conſiſt chiefly of a mixture of calcareous, ſilicious, and argilaceous earth, which do not afford any nouriſhment to the vegetable, but when mixed in proper proportions, they retain and tranſmit the nouriſhment as it is wanted; without ſuch a precaution, plants would have been expoſed to the dreadful alternative of being either parched up by heat, or deluged with water. The ſame ſoil, or mixture of ſimple earths, will not however ſuit every plant, but ought to be varied according as a plant has need of a more or leſs quantity of water, and according as it is neceſſary for its roots to extend to a greater or leſs diſtance.

A ſoil proper for vegetation ought to poſſeſs the following properties. Firſt, it ſhould be of ſuch a conſiſtence as to afford a firm mechanical ſupport to the plant. Second, it ſhould be ſuch as to ſuffer the roots of the plant to extend with eaſe to a proper diſtance. Third, it ſhould be enabled to retain a ſufficient degree of humidity to ſupply the demands of the plant.

In order to obtain theſe properties, it is neceſſary that the elementary earths ſhould be mixed together in proper proportion, for none of them is alone poſſeſſed of the qualities required. Hence likewiſe we ſee the neceſſity of being acquainted with the chemical properties of a ſoil, before we can ameliorate it by tillage. The method of analyzing different ſoils is particularly pointed out in the lecture. In aſcertaining the proportions of the ſimple earths, in order to form the moſt fertile ſoil, regard muſt however be had to the quantity of rain which falls; for it is evident, that where the fall of rain is great, the ſoil ought to be ſuch as not to be very retentive of moiſture, and the contrary.—Hence we ſee the neceſſity of meteorological obſervations to the farmer.

M. Tillet has ſhown, that the moſt fertile ſoil for wheat, in flat countries, where a moderate quantity of rain falls, is compoſed of $\frac{3}{8}$ of argil, $\frac{2}{8}$ of ſand, and $\frac{3}{8}$ of calcareous earth.

As a component part of ſoils, iron muſt not paſs unnoticed, as it ſeems to promote the ſolution of carbon. The iron exiſts in the ſtate of an oxyd, the oxygen of which combining with the carbon of the manure, forms carbonic acid. When the carbon is exhauſted, the iron again oxydates, and is then in a condition to act as before, on freſh carbon which is ſpread on the ground. Paring and burning ought to be practiſed with judgment, for there are only ſome ſoils which will bear it, as nothing exhauſts the ſoil ſo quickly as this operation. Some lands may however be benefited by it, ſuch as peaty grounds, or ſoils covered with a ſward of unprofitable herbage, and containing a ſuperabundance of vegetable matter. The combuſtion ſhould be conducted in as ſlow and ſmothered a manner as poſſible, that the carbon may not be conſumed.

In ſome countries gypſum, or ſulphat of lime, is employed as a manure, but is not much uſed in this iſland; it ſeems to act more as a ſeptic, in promoting the deſtruction of vegetable matters, and conſequently the ſolubility of carbon, than as affording any nouriſhment to vegetables; and hence it is not ploughed in like other manures, but only ſtrewed upon the land, and generally in the month of February, to convert the old graſs quickly into carbon, that it may nouriſh the young.

It has lately been found that ſteeping ſeeds in the oxygenated muriatic acid, had a particularly beneficial effect in producing vigorous and early plants, and that the ſame liquor poured upon the ground has likewiſe a beneficial effect. Does the oxygen here promote the ſolution of the carbon? This ſubject deſerves farther inveſtigation.

LECTURE XXVIII.

AN account is firſt given of the old method of bleaching cottons and linens, and the common modes of bleaching woollens and ſilks, which are well known. The greateſt improvement that has been made in bleaching is that by M. Berthollet, by means of the oxygenated muriatic acid.

Scheele was the firſt who introduced this acid to our acquaintance, and obſerved the effects which it produces on the colouring parts of vegetables; but it was Berthollet who firſt thought of applying it in an extenſive way to the purpoſes of bleaching.

Scheele thought that the oxygenated muriatic acid gas, procured by diſtilling muriatic acid from manganeſe, poſſeſſed but little ſolubility in water; but Berthollet found, that it may eaſily be diſſolved in large quantity in that fluid.

If vegetable bodies of different colours be plunged into the oxygenated muriatic acid, they diſappear more or leſs ſpeedily and perfectly; when the ſubſtance poſſeſſes a mixture of different colouring parts, ſome diſappear more eaſily, and leave only thoſe which moſt effectually reſiſt the power of this agent, but have nevertheleſs ſuffered conſiderable alteration. The yellow colouring matters uſually reſiſt the moſt ſtrongly, but at length they all diſappear, and when the oxygenated muriatic acid has exerted its whole action, it is found reduced to the ſtate of ordinary muriatic acid. Hence it appears, that the colouring matters have deprived it of its oxygen, and have by this combination acquired new properties, at the ſame time they have loſt that of producing colours. From this it was not unnatural to conclude that this liquor might produce the ſame effect upon thoſe ſubſtances which colour cotton and linen, and which it is the buſineſs of the art of bleaching to deſtroy.

M. Berthollet firſt tried the effects of this acid, without any previous preparation of the ſubſtances to be bleached, but he ſoon found, that though he ſucceeded in bleaching his cloth without injuring it, yet it became yellow by keeping; his reflections were therefore directed to the circumſtances of the uſual proceſs of bleaching, which he endeavoured to imitate.

The expoſure of cloth to air in bleach grounds, will not bleach it, for it only combines the colouring matters with oxygen, which renders them ſoluble in alkaline lixivia ; the oxygenated muriatic acid, by imparting its oxygen, produces the ſame effect in a few hours, which is produced by expoſure to the air for a very long time ; he therefore tried alternately the immerſion in oxygenated muriatic acid and alkaline lixivia, and ſucceeded perfectly in producing a permanent white. This mode of bleaching has ſince come into conſiderable uſe, and is undoubtedly a very great improvement. Cloths which required a long time to bleach them, may be now completely finiſhed in a few days ; the new mode of bleaching may be carried on in winter nearly as well as in ſummer, and thoſe fertile meadows, which during the fineſt and moſt productive part of the year are covered with cloth, may be ſubjected to agriculture.

The oxygenated muriatic acid was at firſt procured by diſtilling the muriatic acid from manganeſe in Woulfe's apparatus ; but as ſoon as M. Berthollet had reaſon to hope that the proceſs might be executed in the large way, he endeavoured to diminiſh the price of the liquor, by decompoſing muriat of ſoda, or common ſalt, in the ſame operation which ſerved to form the liquor; which he did, by mixing together in the retort, common ſalt, and the black oxyd of manganeſe, and pouring upon the mixture diluted ſulphuric acid, which expels the muriatic acid from the ſoda in the form of gas, which gas attracting oxygen from the manganeſe, comes over, and is diſſolved by the water in the receiver. The proportions directed by Berthollet are ſix parts of powdered oxyd of manganeſe, ſixteen of ſea ſalt, and twelve of concentrated ſulphuric acid, diluted with an equal quantity of water. In order to judge of the ſtrength of the oxygenated muriatic acid, a ſolution of indigo in the ſulphuric acid may be uſed. Mr. Watt recommends for the ſame purpoſe, a ſolution of cochineal in water.

The apparatus for procuring the oxygenated muriatic acid, has been much improved by different bleachers and chemiſts, and is now very convenient. The moſt approved machines for this purpoſe are deſcribed in the lecture.

LECTURE XXIX.

DYING is the art of tinging cloth, ſtuff, or other matters, with a permanent colour, which penetrates its ſubſtance. It is an art of very great antiquity, and is more or leſs practiſed in almoſt all nations, whether civilized or ſavage.

The moſt remarkable general fact in the art of dying, conſiſts in the different degrees of facility with which animal and vegetable ſubſtances attract and retain colouring matter; or the degree of facility with which the dyer can tinge them with any intended colour.

The ſubſtances to be operated on by the dyer, are animal or vegetable, of which the former are much more eaſily dyed than the latter, and this ſeems chiefly to depend on the difference of their conſtituent parts. The chief chemical difference between animal and vegetable ſubſtances, is, that the former contain only a ſmall portion of carbon, which is the moſt fixed elementary ſubſtance, and a large quantity of hydrogen and azote, both of which are very volatile; while vegetables contain a very large portion of carbon, leſs hydrogen, and in general no azote; and as the azote and hydrogen readily aſſume an elaſtic form, of which carbon is incapable; the wool, hair, and ſilk, in which theſe ſubſtances abound, have leſs adheſion between their conſtituent parts, than what exiſts between thoſe of cotton, linen, &c. and are therefore more ſtrongly diſpoſed than the latter to combine with other ſubſtances, when heated and brought into contact with them; and it is probably in conſequence of this diſpoſition, that wool, hairs, and ſilk, manifeſt ſtronger affinities or attractions for colouring matters, than cotton and linen; it being well known to dyers, that cotton and linen will neither of them receive any colour by the ſame preparation, or in the ſame liquor which dyes wool, or woollen cloth ſcarlet. Wool and ſilk are alſo more readily decompoſed, or injured by acids, alkalies, and other chemical agents; which ought therefore to be more ſparingly uſed in the dying of animal, than of vegetable ſubſtances.

Wool is naturally ſo much diſpoſed to combine with colouring matter, that it requires but little preparation for the immediate proceſs of dying; but ſilk muſt firſt be freed from a kind of varniſh with which it is covered, by boiling either in pure water, or a very weak ſolution of alkali; it muſt then be bleached, by expoſure to the fumes of ſulphur. Cotton and linen are cleared of their tinging matter by boiling them in a ſolution of fixed alkali, they are then to be bleached, either by expoſure to the air and ſolar light on bleach grounds, or by immerſion in the oxygenated muriatic acid. The ſtuff being thus bleached, will not only imbibe the colouring matter of the dye more readily; but being rendered whiter, is more capable of reflecting the light that falls upon it through the colouring matter, and thus exhibits more brilliant tints.

In general the particles of cotton and linen have little attraction for the colouring matters, and therefore could not be dyed but by means of intermediate affinity. The ſubſtance to be dyed muſt firſt be impregnated with a ſubſtance which has an attraction both for it and for the colouring matter, and then when the latter is applied, it will adhere to it firmly. Theſe intermediate or connecting ſubſtances have been called mordants, or baſes; the moſt remarkable are argil, and ſome metallic oxyds.

If the baſe be univerſally applied over the piece of goods, and this be afterwards immerſed in the bath, it will receive a permanent tinge over its whole ſurface; but if it be applied only in parts, the dye will ſtrike thoſe parts only. The former proceſs conſtitutes the art of dying properly ſo called; and the latter the art of printing, ſtaining, or painting.

In the art of printing, the mordant, or baſe, (which generally conſiſts of argil, or iron) is mixed with gum, and applied by means of blocks, or wooden engravings in relief. The piece is then immerſed in a ſolution of cow's dung, which among other effects, ſeems to act by covering thoſe parts to which the baſe has not been applied, with a mucilaginous matter, which renders them leſs capable of receiving the dye. The colours are then brought out in a bath, filled with ſuitable compoſitions; very often a decoction of madder is uſed, and when this is the caſe, if an argilaceous baſis has been applied, the whole will come out of a red colour. With the piece in this ſtate, the printer has only to avail himſelf of the difference between a fixed and fugitive colour. He therefore boils the piece in bran, or brewer's grains, which take up part of the colour, and then the common mode of bleaching takes away the remainder from all parts excepting thoſe to which the baſe has been applied, which will continue of a permanent red. If the baſe be iron, then the part printed will be black, but if it be a mixture of argil and iron, the permanent colour will be purple; and it is evident, that by printing the ſame piece with theſe baſes, both ſeparate and mixed, the three colours will be produced by the bath.

In order to form the argilacious baſe, ſulphat of alumin is mixed with acetite of lead. In this caſe a double decompoſition takes place. The ſulphuric acid uniting with the lead, forms ſulphat of lead, which is precipitated, and thrown away, and the acetite of alumin being formed of a proper conſiſtence by means of ſtarch, or gum, is applied by the blocks; the piece is then expoſed to a ſufficient heat to drive off the acetous acid.

The iron baſis is formed by acetite of iron; and the acetous acid is likewiſe driven off by heat.

The materials for dying are very numerous; ſome produce durable colours, which cannot be diſcharged either by expoſure to the air, or by waſhing with ſoap, others, though they will ſtand the action of ſoap, cannot reſiſt that of the air. The moſt permanent dyes we have, are cochineal and gum lac for fine reds and ſcarlets; indigo and woad for blue; and theſe laſt when mixed with different proportions of the others, for purples and violets; weld, and ſome vegetables, for yellows; and madder for coarſe reds, purples, and blacks.—The fading colours are much more numerous; in this claſs are included log-wood, brazil-wood, peach-wood, red-wood, fuſtic, archil, &c.

Indigo muſt firſt be deoxydated by means of orpiment, or ſugar, it then becomes ſoluble in the bath; but the ſubſtance dyed by it comes out of a green colour, which ſoon changes to a blue by the abſorption of oxygen from the atmoſphere. Sulphat of indigo dyes the ſaxon blue, and the quercitron bark is now much uſed in dying and printing.

There is no art which depends ſo much on chemiſtry as dying, yet its principles are by no means well eſtabliſhed; neither are the facts connected by a ſatisfactory theory; but as chemiſts are now become dyers, and dyers chemiſts, we may hope that this art will ſoon aſſume a more ſcientific form.

LECTURE XXX.

IN the inveſtigation and analyſis of mineral waters, the ſenſible qualities are firſt to be carefully obſerved; theſe are by no means circumſtances of indifference; for they will ſerve to indicate the proceſſes we are to uſe, and ſave much trouble. The phyſical properties, ſuch as ſpecific gravity, temperature, &c. ought then to be well aſcertained. When theſe circumſtances have been obſerved, we muſt examine the water by chemical teſts, or precipitants.

In order to aſcertain whether the water contains any iron, a little tincture of galls, or pruſſiat of potaſh muſt be dropped into ſome of it, and if a purple or blue colour be produced, we may be aſſured that it does contain iron. The next object is to aſcertain whether this metal be ſuſpended by the carbonic acid, or by ſome of the more fixed acids; which may be done by boiling it for a ſhort time, and then examining it by the ſame teſts. If it ſtill changes colour, the iron is ſuſpended by a fixed acid.

The preſence of carbonic acid may be aſcertained by tincture of turnſole. This teſt likewiſe diſcovers the preſence of any other acid, and it may be determined whether it be the carbonic or any other acid, by boiling the water.

Paper dipped in an infuſion of red cabbage, is a delicate teſt of the preſence of both acids and alkalies, the former of which turn it red, and the latter green. Paper on which characters have been written with a ſolution of acetite of lead, is a teſt of the preſence of ſulphurated hydrogen gas. The preſence of the ſulphuric acid is aſcertained by muriat of barytes; that of lime by the oxalic acid; and of alkalies by the aqueous infuſion of brazil wood.

By means of theſe precipitants, varied in a proper manner, we ſhall be enabled to form a judgment of the nature of the contents of a mineral water, which will greatly facilitate the analyſis, and prevent many unneceſſary trials.

The next thing to be done, is to aſcertain the nature and quantities of the aeriform, or elaſtic fluids which theſe waters contain. Theſe gaſes may be beſt procured from the waters by means of a ſimple machine, deſcribed in an eſſay which I publiſhed on the Creſcent water at Harrogate. When the quantity of gas procured has been accurately meaſured, the different kinds muſt be ſeparated from each other.

When carbonic acid and azotic gas are mixed together, if they be agitated over water, that fluid will abſorb the former, but not the latter, ſo that the quantities of each may be aſcertained. When the water contains carbonic acid, ſulphurated, hydrogen, and azotic gas, the bulk of the whole muſt firſt be aſcertained. Some freſh water is then to be put into the machine, and a quantity of quicklime added to it, which will abſorb the carbonic acid gas, and its quantity may be aſcertained, by ſubtracting the remainder procured by the machine, from the whole quantity at firſt procured. What remains is a mixture of ſulphurated hydrogen and azotic gas, the former of which may be ſeparated from the latter by agitation over water, and their reſpective quantities aſcertained. In the analyſis of ſulphureous waters, the ſulphurated hydrogen gas ought always to be ſeparated before we evaporate them, otherwiſe, during the evaporation, part of the ſulphur depoſited by this gas, on its union with the oxygen of the atmoſphere, is converted into ſulphuric acid, which greatly changes the nature of the ſalts contained in the water.

The next ſtep in the analyſis, is to evaporate a conſiderable quantity of the water in order to aſcertain the ſolid contents. The water ſhould firſt be made to boil gently, that the gaſes may be expelled, the matters which they held in ſolution will then be precipitated, and may be collected by filtration; the remainder of the water muſt then be evaporated ſlowly to dryneſs, and the reſiduum collected and weighed.

This reſiduum is then to be put into a phial, and alkohol poured over it to the height of an inch; it muſt be well ſhaken, and after ſtanding a few hours, muſt be filtered. The alkohol diſſolves the diliqueſcent ſalts, ſuch as muriat of lime and muriat of magneſia, but will not touch ſuch as are not diliqueſcent. To the reſiduum, not ſoluble in the alkohol, is to be added eight times its weight of cold diſtilled water; the mixture muſt be ſhaken, and after ſtanding a few hours, muſt be filtered. The riſiduum muſt next be boiled for half an hour, in 500 times its weight of diſtilled water, and afterwards filtered. What remains is now inſoluble either in alkohol or water, and generally conſiſts of argilaceous or ſilicious earths, which may be eaſily ſeparated from each other, and their quantities aſcertained. The ſolution made by boiling in diſtilled water, contains chiefly ſulphat of lime, the quantity of which may eaſily be aſcertained by evaporation.

We muſt next examine the ſpirituous ſolution, which, as was before obſerved, contains in general muriat of lime, and muriat of magneſia; this ſolution muſt be evaporated to dryneſs, and weighed. Diluted ſulphuric acid is then to be poured on the ſalt, which will not only ſhow the preſence of the muriatic acid, by the white fumes diſengaged, but will unite with the lime and magneſia, forming ſulphats with theſe earths, the latter of which is ſoluble, but the former poſſeſſes very little ſolubility; in conſequence of which they can be eaſily ſeparated, and the quantities of muriat of lime and muriat of magneſia eaſily aſcertained, when the quantities of ſulphat of lime and magneſia are known.

The ſolution made in cold diſtilled water is next to be examined, and cryſtallization attempted, which will enable us, with the aſſiſtance of proper teſts, to aſcertain both the nature and quantity of each ſalt which it contains.

When a water has been thus analyzed, we muſt next confirm our analytical proof by ſyntheſis, and if we can produce a water perfectly ſimilar to the water we have examined, we may reſt ſatisfied with our analyſis.

When a water contains lime, diſſolved either by the ſulphuric, carbonic, or any other acid in conſiderable quantity, it is much leſs fit for obtaining extracts from ſolid ſubſtances, for brewing, diſtilling, preparing decoctions of coffee, or infuſions of tea, and many other uſes than pure water, and is uſually denominated hard. Such water is likewiſe more or leſs unfit for waſhing linen, partly becauſe it will not eaſily diſſolve the greaſy matters, but chiefly becauſe it decompoſes ſoap. For theſe reaſons hard waters are totally uſeleſs in bleaching, and are unfit for boiling peas, beans, and other pulſe.

The lime in hard waters is generally ſuſpended by the ſulphuric and carbonic acids. Oxalic acid will ſhow the preſence of lime; muriat of barytes that of ſulphuric acid, and lime water, or tincture of turnſole, that of the carbonic acid.

If carbonat of lime renders the water hard, it may be purified by boiling, which drives off the carbonic acid, and the carbonat of lime ſuſpended by it will be precipitated; but when it is cauſed by ſulphat of lime, a fixed alkali muſt be added, which precipitates the earthy baſe; for this purpoſe a ſolution of common potaſh may be poured into a given quantity of the water as long as it occaſions any turbidneſs, and after the precipitate has ſubſided, we may ſtill try whether the alkali will precipitate any more lime: in this way we may determine the quantity of alkaline ſalt which a given quantity of water requires for its correction, and when once this is done, we can put the proper quantity of the ſalt into the water, let it ſtand a few hours, then decant the liquor from the ſediment, and it will be fit for waſhing, or any common purpoſes. Putrid waters are beſt purified by agitating them in contact with powdered charcoal, which may be eaſily done at ſea, and will render them perfectly ſweet; if the inſides of the water caſks be previouſly charred, they will preſerve the water ſweet for a long time.

THE END.